Applied Silviculture
in the
United States

BY R. H. WESTVELD AND RALPH H. PECK

FORESTRY IN FARM MANAGEMENT

BY R. H. WESTVELD

APPLIED SILVICULTURE IN THE UNITED STATES

Second Edition

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Preface to Second Edition

The 10 years of research that have occurred since the first edition of this book was published have strengthened the scientific basis for applying silviculture in the United States. During the same period the general improvement in economic conditions has broadened the market for wood, especially that for low-value species and low-quality material. For the landowner who is committed to timber growing as a permanent operation this demand makes more intensive silviculture possible. Where formerly unprofitable trees have increased in market value enough to be now harvested at a profit, or at least without monetary loss, instead of girdled or cut and left in the woods, good silviculture can be practiced with less investment in cultural operations. On the other hand, some silvicultural operations are now much more costly than formerly. Planting generally costs nearly twice as much as it did 10 years ago. Profit from planting is therefore unpredictable. The influence of these developments has not been described in the revision of the individual chapters because all regions have been affected similarly. What was a low-value tree 10 years ago is still a low-value tree, but now that tree can be harvested economically whereas 10 years ago it could not be so harvested.

The chief objective in the revision was to include the advances in silviculture in the past 10 years. This has necessitated a few fundamental changes. The most important of these is concerned with the handling of data on prices, costs, and profits. Gradual inflation since 1941, and especially since 1945, makes values expressed in dollars and cents rather meaningless. Most of the monetary values have therefore been deleted. Wherever possible they have been replaced by man-hours of time or by ratios to show relative values. Two other changes of note have been made to conform with the latest revisions in tree names and in forest-type classification. The *Check List of the Native and Naturalized Trees of the United States Including Alaska* (1944) served as the authority for tree names. *Forest Cover Types of Western North America*, which follows the same principles as the

cover-type classification for the eastern United States, is the basis for the forest types of the western United States.

The author again gratefully acknowledges the advice and help of the many persons who contributed to the revision of this textbook. Special recognition is due the teachers of silviculture who used the first edition of the book in their classes and numerous members of the staffs of the federal forest experiment stations. Without the aid of his wife, Amy L. Westveld, in checking references, assembling the revised manuscript, and proofreading, this second edition could not have been completed.

R. H. Westveld

Columbia, Missouri
July 1, 1949

Preface to First Edition

Silviculture is the forester's tool for making forest land productive of tree and animal crops, useful and attractive to the recreationist, and effective in the conservation of soil and water. Regardless of whether the silviculturist has all or only some of these objectives in mind he must understand the fundamental principles of the ecology and economics of the forests with which he is dealing if the practices he chooses are to be financially sound and silviculturally successful. Each forest condition and each locality present peculiar individual problems. Only by years of practice can a silviculturist become expert in a particular region. The student of silviculture can learn much, however, and can broaden his outlook on silvicultural problems by a thorough study of the application of silviculture in the important forest regions of the United States. This book has been organized and written to serve chiefly as a textbook, but the author, by including a comprehensive list of the latest references, hopes that it may be useful also as a reference book for the practitioner who may desire more detailed information on special problems. The student should have had courses in silvics, cutting methods and slash disposal, and forest planting before undertaking a course in applied silviculture.

Timber production is the primary objective of the silvicultural measures that are recommended. The author recognizes that watershed protection, wildlife, and recreational values of forest land will carry considerable weight in determining the intensity and details of the silvicultural measures that are feasible. High recreational or watershed protection values mean that silviculture should be modified or intensified so as to protect these values adequately. Where wildlife is a dominant factor it may be necessary to sacrifice a certain amount of timber-production value to meet the needs of wildlife. In general, however, measures that favor timber production are not inimical to other land uses.

Although a vast amount of fundamental information on the ecology and economics of the silviculture of the forests of the United States is

lacking, forest research workers, in recent years, have supplied many facts that give valuable clues to the silviculture of American forests. Only as more facts become available will improvement in silviculture be possible.

By including slash disposal, disease and insect control, regulation of grazing, control of burning, and control of logging damage the author is using a broad interpretation of the scope of silviculture. Space does not permit a detailed discussion of disease and insect problems; therefore only the more urgent and practical phases are included. Fire protection, so important to success in timber growing, is not included for the obvious reason that the subject is too comprehensive to be treated adequately here.

As a basis for the classification of the forests of the eastern United States the committee report of the Society of American Foresters, contained in Volume 30, Number 4, of the Journal of Forestry, has been used with certain modifications.

The author recognizes that the writing of an authoritative treatise on applied silviculture in the United States is beyond the scope of one person. In recognition of this fact he has submitted each chapter to authorities in their respective regions. Grateful acknowledgment is made to the many members of the staffs of the twelve federal forest experiment stations and to Mr. A. C. Cline for their reviews and for their helpful and constructive suggestions. Acknowledgment is made to these men for their help in selecting suitable illustrations and to the Forest Service of the U. S. Department of Agriculture, the Harvard Forest, the Yale Forest School, the Pennsylvania Department of Forests and Waters, and to Mr. C. B. Bidwell for the use of the photographs. The author also gratefully acknowledges the constructive suggestions made by the teachers of silviculture who, in various forestry schools, have used the original manuscript, which was the basis for this book, as a textbook.

R. H. Westveld

Gainesville, Florida
January, 1939

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1 · *Northeast Spruce-Hardwood Region*

DESCRIPTION AND HISTORY

Location and Landownership

The northeast spruce-hardwood region includes northeastern New York, northwestern Massachusetts, all Vermont and New Hampshire, except the Connecticut River valley and the extreme southern portion of these states, and all Maine, except the southwest portion (Fig. 1). It includes some 20,000,000 acres of forest land, largely in private ownership. Exclusive of farm woodlands, individual forest-land ownership is in tracts of a few thousand to 150,000 acres or more, the smaller areas dominating. More than 600,000 acres of forest land are managed as state forests, while more than 2,400,000 acres are in the State Forest Preserves of New York. More than 800,000 acres are in national forests.

It is estimated that in Maine and New Hampshire forest land constitutes at least 80 per cent of the entire land area, and in Vermont and New York at least 50 per cent.

Physiographic Features

The region is largely mountainous. The most prominent mountain ranges are the Adirondacks in New York, the White Mountains in northern New Hampshire and northeastern Maine, and the Green Mountains in Vermont. Much of the region lies between an altitude of 2000 and 5000 feet, except most of Maine, which lies below 2000 feet. The highest peak in the region—Mt. Washington—reaches an elevation of 6290 feet. The most rugged areas are in the White Mountains in New Hampshire, where, in general, slopes are steep and precipitous. In contrast, the Adirondack and the Green Mountains are characterized by a rolling topography with localized abrupt slopes. The surface is broken considerably by numerous small streams and occasional lakes.

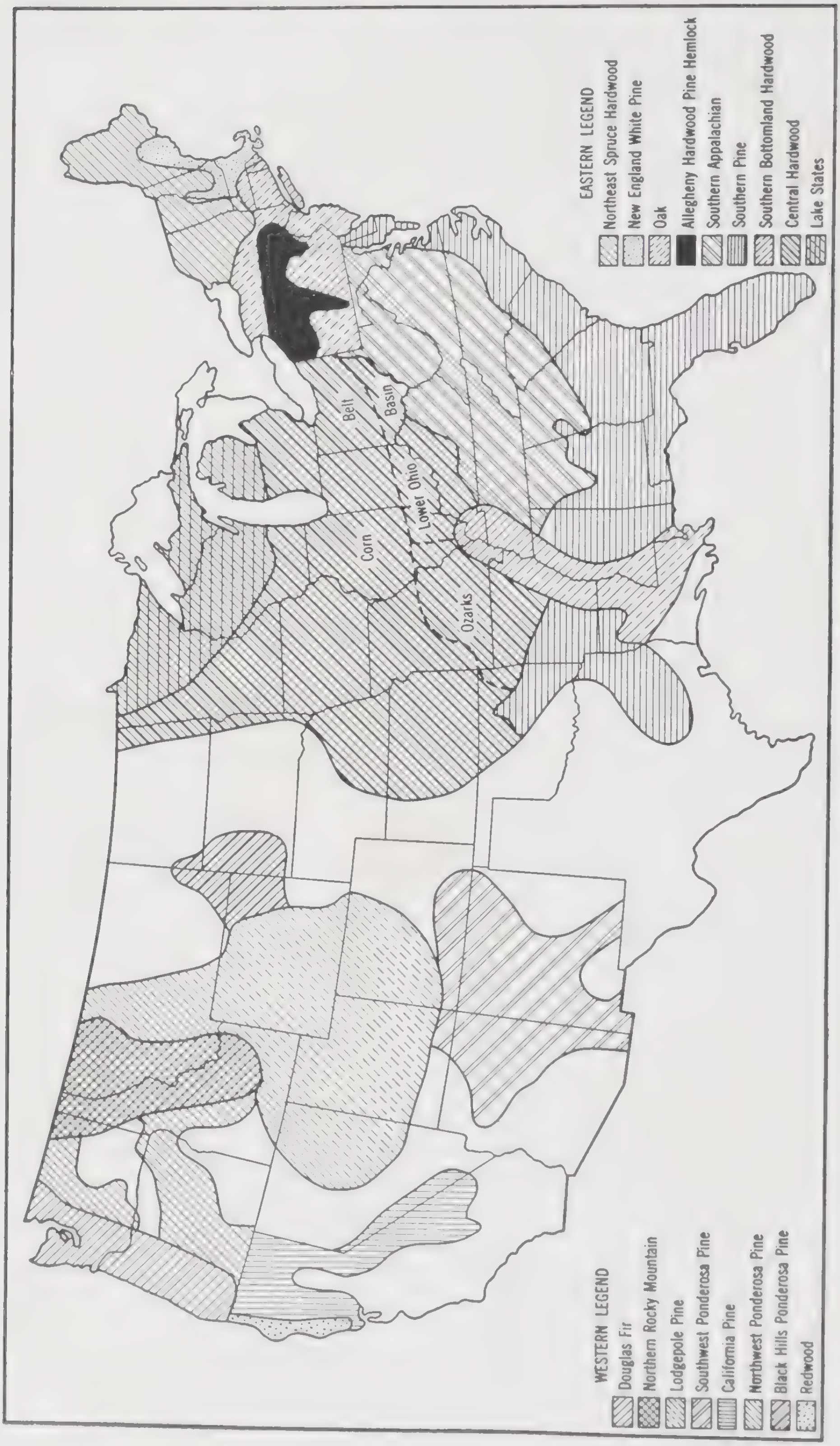

Fig. 1. The forest regions of the United States.

The topography of Maine is relatively level, most of the land surface sloping gently to the south, except the area drained by the St. Johns River flowing north. However, rising conspicuously above the general contour are numerous isolated mountain peaks, some of which rise to an elevation of more than 5000 feet. Lakes and ponds are numerous throughout the state of Maine.

The soils are podsols such as characterize the northern New England states. They are variable in texture, but most of them are either sandy or clay loams. Low, poorly drained areas of muck or peat are distributed rather generally and occupy considerable space in some sections. Most of the mineral soils are shallow and contain an abundance of stones and boulders. These unfavorable soil characteristics and the roughness of the land surface limit the agricultural use of much of the land.

Most of the important rivers of the Northeast have their headwaters in this region. Among the more important rivers are the Hudson, Androscoggin, Penobscot, Kennebec, St. Johns, and Connecticut. These rivers with their numerous tributaries form a fairly complete network.

Climatic Features

The climate is cool and humid. Frequent and sudden changes in weather are common.

Increase in precipitation with increase in altitude is not so marked here as in some sections of the United States. The average annual precipitation for most of the region is between 35 and 40 inches (Weather Bureau 1926). Its distribution during the growing season is remarkably uniform. Dry spells are usually of short duration, and even during the dry months the average monthly precipitation varies from 2.22 to 2.93 inches. The driest periods occur in April or May and in October or November.

Over most of the region, snow accumulates to a considerable depth; 3 to 6 feet of snow on the ground is not uncommon. The average annual snowfall for much of the region is around 100 inches.

Although, generally speaking, winter is consistently cold, the weather is changeable and short periods of relatively mild weather do occur. The mean temperature for January for most of the region is between 15° and 20° F., with occasional days having a temperature above freezing. The summer is usually short and cool. High temperatures are not common, and, even when they do occur in the daytime, the

nights are cool. The mean temperature during July is between 65° and 75° F.

At the high elevations, frosts may occur even during the summer months, but, at the lower elevations, summer frosts are infrequent. Normally, a period of 3½ to 4 months is free of killing frosts.

High humidity is characteristic of the climate. In the absence of rain during the summer, night and early morning fogs help to dampen the atmosphere at least while they last. A relative humidity below 40 per cent is not often recorded under the cover of the forest.

Severe thunder storms are commonly accompanied by heavy rains, usually local but sometimes fairly general. Electrical storms with so little rain as to allow fires to run in the forest litter are rare.

Although winds of high velocity are infrequent, winds of hurricane type such as that of 1938 have occurred and severely damaged the forests. The unevenness of the topography tends to break the force of normal winds.

Development of Lumbering

Although cutting in this region began in the early Colonial days, it progressed rather slowly owing to the inaccessibility of a large portion of the region. Cutting in quantity did not begin until about 1840. Even then cutting operations in Maine and the Adirondack Mountains of New York did not progress on a large scale. The development of iron mines stimulated cutting for charcoal in the Lake Champlain region between 1880 and 1890 (Sterling 1932).

Although some pulpwood was cut before 1900, the paper industry did not make heavy demands until 10 or 15 years later. Spruce and fir were used exclusively for pulpwood when paper was first manufactured. Hardwoods have been employed for pulp increasingly in recent years. Of the domestic pulpwood used in 1944, 1,247,219 cords were spruce and fir, 257,888 cords were other conifers, and 388,386 cords (20 per cent) were hardwoods. Fifty-six pulpmills draw on the timber resources of the region.

The region is not important in lumber production. The heavy demand for spruce and fir for pulpwood has kept the volume of larger saw-log-sized trees low and thus decreased the quantity of this class of material. Not more than 10 to 15 per cent of the timber cut is converted into lumber. This fails by some 20 per cent to meet the lumber consumption of the region.

The Effect of Past Practices

The early cuttings in all the forest types removed only material of saw-log size, that is, chiefly trees 12 inches and larger in diameter. Lumbering was at first confined to land that supported some spruce and eastern white pine, because these were the only species that had much commercial value and they could be transported cheaply by water. Except for a few very accessible localities, hardwoods were rarely cut. Consequently, even now there is a considerable acreage of hardwoods that approach closely the virgin condition.

With the increased demand for pulpwood, many companies changed completely from saw-log to pulpwood production. Diameter-limit cutting to a minimum of 8 to 10 inches on the stump was common practice in the early pulpwood cuttings (Cary 1907), except on areas of great windfall danger or of high fire hazard and logging costs where clear-cutting was applied (Carlisle 1923, Cary 1907). Since 1915, many pulpwood operators have been removing all the spruce and fir down to a diameter limit of 5 inches (Westveld 1930). One paper company cuts more conservatively, cutting spruce and fir to diameter limits of 8 and 6 inches, respectively. Pure or nearly pure softwood stands usually contain a limited amount of young conifers that, if properly protected from fire, will soon develop into a fairly satisfactory stand of pulpwood. However, on nearly all these lands, varying quantities of hardwoods grow in mixture with the spruce and fir, offering considerable competition and thus reducing materially the pulpwood growth possibilities. Consequently, much valuable increment has been lost even on the most favorable sites.

Certain lands were poorly stocked with young coniferous growth. Low-value hardwoods usually seeded in very shortly after cutting and practically took possession of the land for a period of years. Occasionally, these lands reverted to an aspen or paper birch type. This reversion more often took place where cutting was followed by fire. A vast acreage of these forest types now exists.

Where the forest consisted of a mixture of spruce and fir with various hardwoods, the cutting caused much greater deterioration in stand composition than in the pure or nearly pure conifer forest. On the older cut-over areas, a few spruce or fir trees of seed-bearing size were left, thus providing for some restocking by these species after the cutting. Furthermore, these residual trees, because their physical condition was better than that of the small suppressed trees left after heavy cutting, were capable of accelerated growth. Where no hardwoods are

removed (this is the usual practice), the hardwood canopy is very little broken by cutting, and the small residual spruce and fir are usually badly suppressed and remain unthrifty. These trees produce few seed, if any, so that spruce and fir regeneration is very uncertain. Even the advance growth of conifer reproduction and saplings is usually badly suppressed by the hardwoods. The hardwoods have every advantage over the softwoods under any type of cutting that removes only the latter (McCarthy 1919, Westveld 1928, 1931).

In localities where the hardwoods can be utilized, the removal of the timber in all the forest types is more complete than previously described. Although this heavier cutting gives the conifers a somewhat better chance to grow, any advantage they gain is largely temporary, since invading hardwoods that make rapid growth soon overtop them.

Where hardwoods can be marketed, clearcutting has been the usual practice in the northern hardwood types. Such close utilization has not been disastrous silviculturally, because the hardwoods regenerate rather prolifically and the new stand, if given nothing more than fire protection, will produce a fairly satisfactory hardwood forest. Unfortunately, the new forest is frequently composed of species of low value.

Because of the low value and frequently the absence of a market for either quaking aspen or paper birch, these types have seldom been managed. Extensive areas of these forest types have never been cut over.

Slash is seldom disposed of, except where disposal is required by law. Hardwood slash has not had unfavorable effects. Coniferous slash has had a detrimental effect in some cases by interfering with the establishment of reproduction.

Carelessness in logging has also contributed materially to stand deterioration (Westveld 1926). The indiscriminate swamping out of skid roads and the use of small-sized trees of valuable species for corduroy and skidway material have reduced the stocking as well as changed the composition of cut-over stands.

A limited amount of planting of land badly denuded by logging or fire has been done. Planting was a policy adhered to, also, as a regular part of the silviculture practiced by Fernow in the management of certain lands in the Adirondacks (Bryant 1917). His system was practically to clearcut hardwoods as well as spruce and fir, leaving only windfirm thrifty hardwoods and conifers. Slash was then burned and the areas planted with conifers. Several different species were used, the most promising of which were the eastern white pine, Scotch pine, red pine, and Norway spruce.

THE FORESTS AND THEIR MANAGEMENT

The northeast spruce-hardwood region is characterized by a large number of species occurring in different combinations to make up many distinct forest types. Red spruce, balsam fir, sugar maple, yellow birch, and white ash are the most important species. Black spruce, American beech, and paper birch are of secondary importance commercially.

The commercially important forest types fall into two groups, the spruce-fir and the northern hardwood. The spruce-fir group contains six distinct forest types. In two of these, hardwoods are strongly represented. The types included in the spruce-fir category are (1) red spruce, (2) yellow birch–red spruce, (3) red spruce–sugar maple–beech, (4) paper birch–red spruce–balsam fir, (5) black spruce, and (6) balsam fir. The first three types are most extensively distributed. The northern hardwood group is represented by three distinct types: namely, sugar maple–beech–yellow birch, sugar maple, and yellow birch. Any of the spruce-fir or northern hardwood types may be succeeded after fire by any one of the following temporary types: aspen, pin cherry, or paper birch. These three are potential pulpwood types, since it is possible through silvicultural practice to convert them into conifers even though the site may be potentially more favorable for hardwoods.

Under present economic conditions, the yellow birch–red spruce, the red spruce–sugar maple–beech, and the paper birch–red spruce–balsam fir types are operated primarily for the conifers. With the development of improved markets for hardwoods, these types will ultimately assume dual importance.

The northern white cedar and the black ash–American elm–red maple types, commercially valuable in some localities, are discussed fully on pp. 347 and 107, respectively. The pin cherry type, not extensive in area, presents the same problems as the aspen, except that there is less possibility of utilizing it.

SPRUCE-FIR TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. The six spruce-fir types are described in Table 1. Formerly the red spruce type was described as four distinct types (actually sites), namely, spruce flat, spruce slope, spruce swamp, and old field spruce. Generally the spruce swamps are

TABLE 1

Description of Spruce-Fir Types

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Red spruce (1)	Major	High	Moist flats, slopes, ridges, and knolls	Red spruce Balsam fir Yellow birch Paper birch Red maple	Sugar maple American beech Northern white cedar Hemlock Eastern white pine White spruce	Near climax on moist flats and on thin soils at high elevations
Yellow birch–red spruce (2)	Major	Moderate	Lower slopes, benches, and moist well-drained flats	Yellow birch Red spruce Balsam fir Red maple Paper birch Northern white cedar	White spruce Sugar maple American beech	Probably climax on moist flats
Red spruce–sugar maple–beech (3)	Secondary except in Adirondack Mountains	Low, unless hardwoods are readily marketable	Well-drained fertile soils of lower slopes, benches, and ridges	Red spruce American beech Sugar maple	Hemlock Red maple Yellow birch	Climax type
Paper birch–red spruce–balsam fir (4)	Minor	Moderate	Same as Types 1 and 2	Paper birch Red spruce Balsam fir	Quaking aspen Red maple Yellow birch Eastern white pine Northern white cedar	Temporary type
Balsam fir (5)	Minor	Moderate	Similar to Types 1 or 6	Balsam fir Yellow birch Paper birch Red maple	Red spruce White spruce Hemlock American beech Eastern white pine	Usually temporary except in zone below timber line
Black spruce (6)	Minor	High	See page 339.			

occupied by black spruce, and the old fields by white spruce or red spruce or by mixtures of these species.

The stands are dense on the upper slopes, and the yield of timber is usually large. High yields are characteristic also of the old field red spruce.

Eastern white pine, originally an important element of the red spruce type, was largely eliminated in the early cutting.

The red spruce type is mostly even-aged, except where early diameter-limit cutting has transformed the forests into uneven-aged stands. Variation in age and density is characteristic. Stand volumes vary from 2 to 15 cords per acre, except in old field or virgin stands, where they may exceed 50 cords per acre. The vegetative covering is usually fairly dense, but it is particularly so where recent cutting has opened the stand.

The abundance of the hardwoods in the yellow birch–red spruce and the red spruce–sugar maple–beech types reduces their value for pulpwood, although the red spruce develops excellent bole form here. These mixed hardwood-conifer stands are ordinarily uneven-aged, the spruce and fir often occurring as an understory beneath the predominant overmature hardwoods. The hardwoods are usually poor in form and contain much defect. The average stand does not contain more than 5 or 6 cords of spruce and fir.

The paper birch–red spruce–balsam fir, the balsam fir, and the black spruce types resemble the red spruce type in form and density. They are not so valuable commercially.

Stand Regeneration and Development. The comprehensive studies of the spruce-fir cut-over lands by Westveld point to the factors that contribute to success or failure in regeneration and ultimate development of the new stand (Westveld 1931).

General Principles. The quantity of advance spruce and fir reproduction varies with the amount of spruce and fir in the original stand (Figs. 2 and 4), the number of spruce and fir seedlings increasing from 1500 per acre in a stand with a basal area of 20 square feet to 4000 per acre in a stand with a basal area of 120 square feet per acre (Westveld 1931). This relationship accounts for the approximately two-to-one supremacy of the hardwoods over the conifers in the advance reproduction of the yellow birch–red spruce and red spruce–sugar maple–beech types, and it makes the regeneration and stand development problems after cutting more difficult in these types than in the red spruce. Thinning stimulates the establishment of coniferous reproduction in old field red spruce stands (Snow 1938) (Fig. 8).

Losses of advance spruce and fir reproduction during and after logging are often so great, owing to carelessness and the alteration in site caused by lumbering, that the future success of the new stand depends on reinforcement by subsequent reproduction. Average losses during logging approximate 18 per cent of the conifer reproduction, equivalent to 800 seedlings per acre (Westveld 1926). The fact that

Photograph by U. S. Forest Service.

Fig. 2. Abundant spruce and fir reproduction is often present in many spruce-fir stands before cutting. This excellent nucleus for a second crop makes clear-cutting feasible on some lands.

this loss is greatest in the larger seedlings is significant because they would be better able to survive the competition of brush and hardwood reproduction and sprouts than would the smaller seedlings.

Advance conifer reproduction, frequently concentrated on moist decayed wood, suffers high mortality after heavy cutting because of the rapid desiccation of the rotten wood.

If advance reproduction is not present in sufficient quantity to create a well-stocked stand, enough spruce and fir trees of a size to produce seed in quantity immediately and ample canopy to keep the soil from drying out are essential for successful subsequent regeneration of spruce and fir. These requirements result from the ease with which the hardwoods reproduce both by seed and by sprouts, the more rapid growth of the hardwood reproduction, and the rapid invasion of under-

brush and intolerant hardwoods after the opening of the canopy, which make the site less favorable for spruce and fir with each passing year. An exposed mineral-soil seed bed favors the establishment of seedlings of all tree species, particularly red spruce, of the spruce-fir types (Westveld 1931). Better establishment of seedlings in mineral soil than in litter is apparently due to more favorable moisture conditions in the former seed bed (Moore 1917, Murphy 1917, Westveld 1931).

Effect of Competition. Spruce and fir seedlings are subjected to much competition because of the general abundance and rapid growth of their hardwood associates. Weeds and shrubs also compete with the conifer seedlings, but since they do not grow tall their effect is limited to the smaller reproduction; therefore, they are less damaging than hardwood sprouts and seedlings.

The mountain and striped maples, both low-value species, are among the most serious competitors of conifer seedlings because of their habit of producing widespreading clumps, their rapid growth, and their high degree of tolerance. Since they are short-lived, their effect does not extend over so long a period as that of the tolerant beech and sugar maple, both long-lived trees. Paper and yellow birch, pin cherry, and quaking aspen reproduction quickly overtops spruce and fir seedlings, but they do not seriously impair the growth of the spruce and fir, at least during the early years, as do the species previously mentioned. Residual hardwoods, often found in considerable numbers in cut-over stands of yellow birch–red spruce and of red spruce, sugar maple, and beech, also offer serious competition to conifer seedlings.

Not only does competition from the various elements of the stand reduce the growth of spruce and fir seedlings, but it also causes their death, particularly when the competition continues for 10 or 15 years or more. Because the tolerance of balsam fir decreases with age, it has a higher mortality than spruce, giving an advantage to the latter.

Response to Release. Spruce and fir seedlings have the ability to recuperate after suppression. Increased growth may occur during the first year after release, but often 3 or 4 years elapse before a marked increase is noticeable (Cope 1934, Plice and Hedden 1931). Growth usually reaches its maximum at about 10 years after removal of the residual stand (Fig. 3).

Young hardwoods that invade newly cut-over lands have no appreciable effect upon the growth of conifer seedlings for 4 or 5 years, at which time growth may be reduced by two-thirds (Westveld 1931).

Balsam fir responds to release from both residual trees and young hardwoods more quickly than does red spruce. Of the suppressed

class of spruce and fir seedlings those between 2 and 5 feet tall make better recuperation after cutting than either larger or smaller ones (Fig. 3). The larger reproduction, because of long suppression, has insufficient crown, and smaller reproduction is not favorably situated to make immediate increased growth.

Red Spruce Type. Actual conditions in the red spruce type give the conifers a reasonably good chance of maintaining their representation.

Photograph by U. S. Forest Service.

Fig. 3. Spruce and fir reproduction 2 to 5 feet tall makes rapid growth if released from residual hardwoods. Cutting or girdling hardwoods to release conifer reproduction is a distinct aid in maintaining the representation of conifers.

Since spruce and fir predominate in the advance reproduction and since the hardwoods do not make rapid growth, the former are able to hold their own and actually outstrip the latter eventually. This is due in part to the fact that the subsequent hardwood reproduction is largely paper and yellow birch and pin cherry. On the spruce flats, raspberry, brake fern, blueberry, and witch hobble come in abundantly after cutting; but, since they rarely attain a height of more than 4 or 5 feet, they compete chiefly with the smaller reproduction. Under natural competition fir increases somewhat at the expense of the spruce. Everything considered, it is not difficult to maintain a satisfactory stand of pulpwood species on cut-over lands of the red spruce type.

Yellow Birch–Red Spruce and Red Spruce–Sugar Maple–Beech Types. The predominance of the hardwoods in the advance repro-

duction, their rapid growth, and the abundant regeneration of the hardwoods after cutting make the future of the spruce and fir seedlings uncertain where competition is not controlled (Fig. 4). Even though the conifers may be rather well represented in the advance growth, the hardwoods soon dominate the stand by their prolific regeneration after cutting. Spruce usually exceeds fir in numbers in the advance growth,

Photograph by U. S. Forest Service.

Fig. 4. Mixed spruce-hardwood stands, particularly those in which American beech and sugar maple are important components, are likely to support an understory of hardwoods. When the mature stand is cut, these faster-growing hardwoods tend to crowd out the slower-growing spruce and fir. However, in the red spruce–yellow birch type (also in the mixed spruce-hardwood classification) normally abundant advance spruce and fir reproduction occurs.

but the superior subsequent regeneration of fir soon alters the situation. It is therefore difficult to secure a good representation of conifers, particularly spruce, in the ultimate stand without considerable effort. This is particularly true in the red spruce–sugar maple–beech type.

Windfall. Windfall is most serious in the red spruce, the paper birch–red spruce–balsam fir, and the balsam fir types, because root development is restricted, owing to the wetness of the sites, and there are few deep-rooted hardwoods to protect the conifers (Murphy 1917). Early reports that red spruce was more subject to windfall than balsam fir have not been substantiated by Recknagel (1936), who found greater windfall losses in balsam fir. He found that windfall loss may exceed increment in the early years after cutting, especially in stands

composed chiefly of spruce and fir (Fig. 5). Windbreakage is more common in the spruce and fir stands, this damage being associated with the weakness of the trunk caused by butt rot. Both forms of damage are usually spotty, although they may occasionally extend over considerable area.

Photograph by U. S. Forest Service.

FIG. 5. Heavy partial cutting causes much windfall of red spruce because its root system is shallow, especially on thin rocky soils.

ECONOMIC BASIS

Utilization and Marketing Problems. The facts that the raw products of the spruce-fir types must generally be transported to wood-using plants by water and that the quality of the older hardwoods is inferior have made profitable utilization of the bulk of hardwoods next to impossible. The conifers present no such problem. Both spruce and fir are in active demand, being used almost exclusively for pulpwood. This strong demand, the light volumes of pulpwood per acre, and the shortage of pulpwood supplies in New England are responsible for the cutting of small trees down to 5 inches d.b.h., trees which by themselves cannot be handled at a profit. Per-cord cost of producing pulpwood on small operations decreases rapidly as tree diameters increase from 5 to 8 inches (Jensen 1941). Pulpwood from 13-inch trees can be produced for slightly more than half the cost of wood obtained from 5-inch trees. Little difference in logging costs was found on clear-cut and selectively cut areas, and the investigators believe that partial

cutting could be done more economically than clearcutting if various phases were coordinated more closely and minor modifications in method made (Belotelkin, Reineke, and Westveld 1942).

Hardwoods, especially second-growth hardwoods, are being employed in increasing quantity in the manufacture of certain types of paper. It seems likely that further research will increase their usefulness in paper manufacture. This possibility will not change the situation for defective hardwoods, since pulpwood must be sound. Furthermore, unless railroad or highway transportation is expanded, or some other scheme is developed for getting the hardwoods to the mills, there will continue to be many areas from which it will be impracticable to remove the hardwoods. The development of cutting and seasoning processes to dry out the hardwoods so that they will float has been suggested as a means of solving the hardwood transportation problem (Frank 1929), but little has been done to accomplish this.

Growth and Rotation. The productive capacity of spruce-fir lands is shown by yields for fully stocked, even-aged, spruce-fir stands. At 70 years pulpwood yield in trees 4 inches and larger is 14.7, 54.2, and 85.3 cords for the poorest, average (site index 50), and best sites, respectively (Meyer 1929). These rates of growth are not being attained on most of the spruce-fir acreage. Forest type, elapsed time since cutting, stand density, and composition are the most important factors influencing growth on cut-over lands (Westveld 1941).

Annual growth per acre in trees 6 inches and larger will vary from 0.11 to 0.17 cord over a 40-year period on secondary softwood sites and from 0.21 to 0.24 cord over a 50-year period on dominant softwood sites. However, growth during the first 10 years following cutting may be very disappointing as was found in one case in which no net growth occurred during the first 9 years after cutting by four different methods, owing to excessive mortality (Recknagel and Westveld 1942). Maximum growth of spruce and fir cannot be expected where hardwoods constitute a large part of the stand. In one instance the elimination of a part of or all the residual hardwoods, where they made up 100 square feet or more per acre of basal area, caused an increase over a period of 30 or more years of two to three times in diameter growth and of eight to fourteen times in volume of trees 2.6 inches and larger d.b.h. (Westveld 1937).

Thinning appears to have a favorable effect on the growth of second-growth stands. In one case three low thinnings at 55, 64, and 84 years removing 20, 33, and 20 per cent of the stand basal area resulted in an increase in growth of 68 cubic feet per acre annually (Snow 1938).

Balsam fir grows faster than red spruce (Meagher and Recknagel 1935, Recknagel 1922). The smaller trees exceed the larger in rate of growth. Decline in rate of growth is especially pronounced when spruce passes a diameter of 13 inches and fir passes a diameter of 9 or 10 inches.

Meyer (1929) fixes the pulpwood rotation at 56 years for the better sites and 79 years for the poorer sites. The saw-log rotation, placed at 80 to 90 years, is impractical for balsam fir because of excessive loss from decay (see p. 26).

Financial Aspects. Liberation cutting and weeding are recognized as sound investments in the spruce-fir types; as a matter of fact, spruce and fir cannot be grown successfully on some areas without such cultural operations. Girdling of residual hardwoods, part of which was on an experimental basis, has required from 1 to 2½ man-hours of work per acre (Cary 1928, Churchill 1927). The time requirement varied with the skill of the labor and the method of girdling employed. In one instance investment in girdling involving two different degrees of release of spruce and fir resulted in an increased yield of pulpwood in 40 years valued at sixteen to twenty-two times the investment in the girdling operation (Westveld 1937).

The financial aspects of weeding are not so simple. A single weeding requires 2 to 8 man-hours per acre, depending upon age, density, and composition of the stand, and the degree of weeding. Moderate weeding in stands cut over not more than 10 years previously appears most likely to be a financial success (Westveld 1935). Where the hardwoods are 4 inches d.b.h. and 15 feet or more tall, weeding probably is not justified unless the material taken out can be marketed. Combined liberation cutting and weeding applied on an extensive scale required an investment of 6 man-hours of labor per acre (Parsons 1936).

Thinning apparently can be done at a profit when trees 4.6 inches d.b.h. and larger are removed.

Application of Methods

In the application of any type of cutting, either reproduction or intermediate, in the spruce-fir type, stand differences must be recognized and the cutting varied in accordance therewith (Baker and McCarthy 1920; Spaulding, Grant, and Ayers 1936; Westveld 1930). Composition, density, and form of stand, character, amount, and height of reproduction, and character of the soil should be carefully considered in applying cutting measures. The strong tendency toward domi-

nation by hardwoods in the red spruce–sugar maple–beech type, making its conversion into a softwood type costly and the results uncertain, should constantly be borne in mind. Likewise the fact that in many sections sound hardwoods will eventually be marketable makes unwise the voluntary destruction of hardwoods to obtain only a partial stand of spruce and fir, particularly so on the more accessible areas. In all the spruce-fir types supporting advance conifer reproduction where the conifers are to be favored, postponement of cutting until this reproduction attains a height of at least 2 feet is worthy of consideration, because the larger seedlings are destined to a satisfactory future at a minimum cost.

Red Spruce Type. Cutting methods that are most effective in the red spruce type are, in large part, applicable to the balsam fir and black spruce types as well as to most of the yellow birch–red spruce and the paper birch–red spruce–balsam fir types.

Clearcutting. In mature stands stocked with at least 500 well-spaced, thrifty spruce and fir seedlings per acre, clearcutting should be applied (Westveld et al. 1944). All trees 5 inches d.b.h. and larger should generally be removed, unless small numbers of spruce and fir above this minimum diameter are scattered through relatively large areas of young timber, in which case these blocks should be left intact because logging would be costly and disruption of the canopy might lead to windfall.

Shelterwood Cutting. Where advance conifer reproduction is inadequate the shelterwood method of cutting should be used. It creates favorable conditions for regeneration of spruce and fir, and, if properly applied, it controls windfall. The merchantable pulpwood should be removed in two cuttings, the first removing from one-fourth to one-half of the trees. The second cutting, which removes the remaining stand of spruce and fir, can be made in 5 to 10 years after the first cutting. It should be made only after the reproduction is large enough to withstand exposure.

The first cutting should aim at the removal of smaller trees, a maximum of balsam fir—especially the classes most susceptible to spruce budworm (p. 26)—and windfall-susceptible trees, in so far as their removal does not create large openings that might endanger the stand. This practice tends to minimize subsequent windfall losses and favor the spruce over the fir.

Selection Cutting. Selection cutting that has as its objective the production of pulpwood, saw logs, and Christmas trees can be advantageously applied to old field farm woodlands that are from 40 to 60

years old and at least 40 per cent spruce (Kraemer 1937) (Figs. 6 and 7). The first two cuttings should be chiefly for pulpwood and Christmas trees. The first cutting, removing not over 40 per cent of the basal area of the stand, should remove (1) large over-limby spruce and fir, except those that are needed for seed production or wind protection along stand margins, (2) crowded trees in dense groups, (3)

Photograph by U. S. Forest Service.

Fig. 6. An old field red spruce stand (90 per cent red spruce) that can be handled effectively by selection cutting when saw logs and pulpwood are to be the chief products.

the larger balsam fir, and (4) low-value hardwoods (girdling may be substituted for cutting). The second cutting, 10 to 20 years after the first, should be a combination thinning and reproduction cutting, removing not over 35 per cent of the basal area of the stand. The third cutting, at an age of 80 to 100 years, should remove chiefly the spruce crop trees for saw logs. Cleaning should be done at any time when needed during the rotation, always freeing the spruce.

Cultural Operations. Cultural operations should occupy an important place in the management of many red spruce stands. They need not be so intensive as in the types containing a larger proportion of hardwoods, but they should follow the same general scheme. The details of these practices are outlined in the discussion of cutting meas-

ures for the yellow birch–red spruce and the red spruce–sugar maple–beech types (p. 21).

Yellow Birch–Red Spruce and Red Spruce–Sugar Maple–Beech Types. The sort of treatment most practical for these types must be determined by (1) the species and number of hardwoods composing the stand, (2) present and prospective future market for hardwoods,

Photograph by U. S. Forest Service.

Fig. 7. The stand shown in Fig. 6, after selection cutting. Most of the large over-limby spruce and fir trees were removed, together with the larger firs. In addition, dense groups were thinned and low-value hardwoods were cut. Fifty-five per cent of the volume was cut.

and (3) the relative cost of managing the forest primarily for spruce and fir or for mixed crops of conifers and hardwoods. Especially in those stands composed of a large proportion of sugar maple and American beech, it is almost impossible to secure high yields of spruce and fir without intensive silviculture. There is some question as to whether intensive silviculture will pay. On less accessible sites (areas) poorly suited to hardwood production, hardwoods may never be a profitable crop. Elsewhere the second-growth hardwoods can now be disposed of at a profit, and it is likely that their future value will be even greater. Mature hardwoods have little present or future value. As implied earlier, production of large yields of spruce and fir may be so costly

that, for the present, mixed crops of conifers and hardwoods, secured at less expense, may be equally, or more, profitable.

In general, therefore, the red spruce–sugar maple–beech type should be managed for mixed crops (except in special, favored localities), and the yellow birch–red spruce type for crops consisting chiefly of spruce and fir. The spruce flats of the red spruce type will often have to be handled in the same way as the yellow birch–red spruce type.

Preliminary Girdling of Hardwoods. In any of the stands of yellow birch and red spruce or of red spruce, sugar maple, and beech, where the hardwoods cannot be harvested profitably, girdling of hardwoods several years in advance of the reproduction cutting is strongly recommended, for it provides larger initial yields of pulpwood and enhances the chance for larger subsequent yields (Committee Report 1932). Gradual release by not less than three girdlings is preferable to release by a single operation. Starting 15 years before the initial cutting of spruce and fir, the first girdling should release all spruce and fir over 5.5 inches d.b.h.; the second, all spruce and fir over 2 inches d.b.h.; and the third, all spruce and fir reproduction over 4 feet tall. Where it is not feasible to make three girdlings, a single girdling to release the marketable pulpwood should certainly be applied at least 10 years before harvesting this material.

If the hardwoods can be marketed, they should be removed, where the character of the stand permits (where there is no danger of excessive windfall) several years before the cutting of the spruce and fir (Westveld 1930). This removal accomplishes much the same result as girdling except that invasion of hardwood reproduction is more serious after the cutting. When the conifers are cut (this cutting being in reality a removal cutting), a weeding should be applied to give the spruce and fir seedlings an advantage, unless the conifer reproduction is of sufficient height to make a weeding unnecessary.

Clearcutting Followed by Planting. Clearcutting followed by planting and subsequent cleaning is the ideal method of managing the red spruce–sugar maple–beech type for the production of spruce and fir when advance conifer reproduction is deficient. Since this treatment is costly it is rarely justified. Only where markets are the best might this method be feasible.

Clearcutting. Stands accessible to a market for hardwoods and supporting adequate advance reproduction of spruce and fir of the proper size can be handled successfully by clearcutting. This form of management is almost certain to be successful in fostering the spruce and fir in the spruce flats of the red spruce type and in the yellow birch–red

spruce type if the cutting is not done until the advance reproduction attains a height of at least 2 feet. The few defective hardwoods of these types left standing will soon become decadent, making liberation cutting unnecessary. Clearcutting in the red spruce–sugar maple–beech type is not likely to be successful unless the advance reproduction is at least 4 feet tall. If ample small reproduction is present in any of these mixed conifer-hardwood stands, a preparatory cutting or girdling of some of the larger hardwoods is suggested in order that the reproduction thus released may attain sufficient size to insure its future before the clearcutting is made. Cleanings are ordinarily necessary in stands that have been clearcut.

Cultural Operations. Some liberation cutting and cleaning are essential in nearly all spruce-fir stands. Stands composed entirely of spruce and fir or in which the hardwood elements are chiefly yellow and paper birch need no liberation cutting because of the rapid deterioration of the hardwoods after heavy cutting. The kind and the frequency of cleanings depend on the nature of the hardwood components, stands in which sugar maple, American beech, and red maple are present demanding the greatest attention.

Girdling or poisoning are the most effective and cheapest means of ridding the stand of trees over 4 inches in diameter. Girdling should not be attempted until 3 or 4 years after the reproduction cutting. The development of the reproduction and the deterioration and windfall of residual trees which occur during that time alter the stand and give a different conception of what treatment the stand really needs. Discretion must be exercised in girdling. Selective girdling should always be the preferred practice. Only vigorous trees that are actually competing with small spruce and fir should be treated.

In localities where hardwoods have a prospective value in the near future, special care must be taken in girdling; generally it is unwise to treat trees that are sound and well formed. In stands composed of more than 125 hardwoods per acre, liberation cutting should not be attempted unless evidence on the ground shows a good stand of spruce and fir reproduction.

If girdling is to accomplish its intended purpose, the work must be done efficiently. Westveld (1942) advises that the method of girdling should be selected on the basis of conditions encountered. He recommends that notching be used only on trees with infolding bark or other irregularities, that peeling be used freely during the bark-slipping period, and that, if labor is inefficient, double barking be employed.

The universal presence of rapid-growing, low-value species in spruce-fir forests makes cleaning an essential management practice where maximum timber yield is the objective. A single weeding 8 years after the reproduction cutting is usually adequate in stands composed predominantly of spruce and fir such as the red spruce type (except for the more productive spruce flats and lower spruce slopes). In occasional stands a second cleaning may be necessary. Two or three weedings, the first 5 to 7 years after cutting and the second and third (if necessary) at intervals of 4 to 5 years after the first, are needed in the red spruce–sugar maple–beech and most productive yellow birch–red spruce types (Westveld 1935). The best criterion for the exact time to weed is the growth and thrift of the spruce and fir crop trees. As long as they make 6 inches annual height growth and appear thrifty, weeding is not urgent.

Moderate weeding of a selective type is most effective and economical. Especially in the red spruce–sugar maple–beech type it is unwise to cut the hardwoods too severely; the better-formed trees of the more valuable species should be retained. Such low-value species as American beech and red, mountain, and striped maples should be entirely removed from the stand. Partial severance of the stem is the best practice for these maples as well as for pin cherry because it reduces coppicing.

Extensive areas of old cut-over lands on which cleanings have not been applied are in need of treatment. Lands cut 5 to 15 years ago should be given first consideration, preference being shown to those under 12 years old because they will respond more quickly and the work will cost less. In stands cut more than 15 years ago the cutting will take the form of improvement cutting.

Small areas of fully stocked immature stands must be thinned. Experience to demonstrate desirable thinning practice is meager. If the habits of spruce and fir are considered, it can safely be recommended that thinning be light, from beneath, and frequent (probably every 10 years) to minimize the losses from windfall (Fig. 8).

Planting. For the present, planning should be confined to denuded and abandoned farm land. The author takes exception to Jones's (1931) conclusion that planting has no place in the silviculture of the spruce type because of the high cleaning costs, and he takes the viewpoint of Preston (1927), who considers forest planting of denuded spruce sites to be one of the most promising opportunities in spruce forestry.

Planting of pulpwood species, particularly red and white spruce, is recommended for sites to which they are adapted and where the danger

Photograph by U. S. Forest Service.

Fig. 8. A vigorous growth has been maintained and a stand of reproduction (2800 stems per acre) established in this 84-year-old, old field spruce stand as a result of three thinnings at 20-year intervals that removed 20, 33, and 20 per cent, respectively, of the basal area.

of excessive competition from tolerant hardwoods is not great. Norway spruce, although showing during early life every indication of excellent growth and development, should not be used extensively until its true worth is proved.

Three- or four-year transplants have proved to be the most satisfactory planting stock. Seedlings may be all right on areas devoid of vegetation, but such areas are of little consequence. Planting may be done either in spring or fall (Baldwin 1938), preferably the spring. Hole planting has the advantage over slit planting of producing more rapid growth of the planted trees. A spacing of 6 by 6 feet is recommended.

Slash Disposal

Slash in Relation to Fire

Slash is heavy where clearcutting is applied to pure conifer stands (Fig. 9). It is lighter in mixed stands or partially cut stands. Spruce

Photograph by U. S. Forest Service.

Fig. 9. In an even-aged red spruce stand in which all the trees are large enough for pulpwood, clearcutting results in almost complete denudation. Slash is heavy and, unless advance reproduction is present, restocking is slow and uncertain.

and fir slash adds to the fire hazard for 10 to 12 years and is completely decomposed under average conditions in 29 years. Hardwood slash has lost much of its fire-hazard potential after 3 years, but it is not completely decayed until 17 years have elapsed (Spaulding and Hansbrough 1944*b*). A short rotation and partial cutting hasten the decay

of all types of slash. Lopping also quickens decay except on wet sites where waterlogging of the lopped slash as it comes more completely in contact with the soil slows decomposition. Except for short periods of dry weather, slash inflammability is low owing to the generally damp condition of spruce-fir sites.

Ecological Effects of Slash

Logging slash is more detrimental than beneficial to reproduction. Mortality of advance reproduction caused by logging slash, which varies from 47 per cent in dense slash to 26 per cent in light slash, is heaviest among the smaller seedlings, those 6 to 12 inches tall (Westveld 1931). Spruce suffers more than balsam fir. Conifer slash is more destructive than hardwood slash because of its greater density and tendency to mat down badly (Plice and Hedden 1931). Although it has been reported that slash apparently does not aid in the establishment of subsequent reproduction of conifers (Kittredge and Belyea 1923) (Fig. 9), some silviculturists are now inclined to believe, basing their conclusions on their observations, that light slash benefits spruce and fir seedlings.

Economic Considerations

Complete disposal of slash by piling and burning is expensive, generally costing a sum equal to one-third to one-fourth of the stumpage value of the timber. Some authorities believe that, although this is an effective fire-protection measure, partial disposal followed by intensive protection, costing 40 to 50 per cent as much, is a real saving and does not endanger the timber investment unduly (Brown 1923).

Application of Methods

Slash in the spruce-fir forests should always take the form of partial disposal—disposal being restricted to coniferous slash. The degree of disposal varies with the forest type, being most complete in red spruce because there the coniferous slash is often heavy (Fig. 9). The author supports Brown's view (1923) in recommending partial disposal followed by intensive fire protection for the majority of spruce-fir lands. Over limited areas, complete disposal by piling and burning or swamper burning is necessary to combat a high fire hazard.

In the yellow birch–red spruce and red spruce–sugar maple–beech types slash disposal by burning is not often needed. Some burning, supplemented by scattering the slash when it is so dense that it interferes with reproduction, is essential on limited areas (Westveld 1933).

Since lopping does not give slash substantial ecological or fire-hazard-reduction advantages and is costly, this form of slash treatment is not recommended.

Disease and Insect Problems

Ecological Basis

Decay is a limiting factor in the value of balsam fir because of its prevalence at a relatively young age and its capacity to reduce greatly the merchantable volume of wood. Three organisms are responsible for 95 per cent of the cull in balsam fir. *Top rot* is the most damaging, followed in order by *brown butt rot* and *white string butt rot* (Spaulding and Hansbrough 1944*a*). These rots generally gain a foothold at about 40 years and are severe at 70 years. Attack by the top rot fungus, which is responsible for 54 per cent of the cull in balsam fir, is especially prevalent in trees that have developed flat tops as a result of extreme suppression. Red spruce is attacked by the same fungi, but damage does not occur so early in life nor is it so extensive as in balsam fir.

Most of the mature and overmature hardwoods are affected by rot, many of them so badly that they contain little merchantable wood.

The *spruce budworm* is a constant threat to the productivity of the spruce-fir forests. The epidemic that developed in Canada in 1935 began to alarm foresters in the United States when, in 1944, increased budworm activity was evident in Maine. A year later light to heavy infestations were observed throughout the region. In 1946 infestation had become particularly heavy in New York, where it declined noticeably the following year. In Maine, however, infestation was becoming more severe during 1947. Balsam fir, especially overmature decadent trees, are highly susceptible to attack, much more so than the spruces (Westveld 1946). Stands containing a high percentage of fir are most likely to be seriously damaged, if attacked.

The *bronzed birch borer,* once regarded as the primary cause of the decadence and death of yellow birch in spruce-fir stands, was found, upon investigation, to be a secondary agency in the deterioration (Spaulding and MacAloney 1931).

The *European spruce sawfly,* first observed in 1929, has been the cause of the death of spruces, particularly white spruce. Baldwin (1939) estimated that in New England alone 5,000,000 board feet of

spruce was seriously damaged by defoliation. He saw little hope of eradicating the insect but predicted that parasites might hold it in check. Later a disease was reported to be causing heavy mortality among the more heavily infested areas (Dowden 1940).

The *balsam woolly aphid*, which may attack either the terminals of branches or the main trunk, mostly below 12 to 15 feet, is reported to be doing damage in Vermont, New Hampshire, and Maine. Studies, chiefly in Maine (Brower 1947), show that severe infestations develop on sites unfavorable to the growth of balsam fir—especially on low-lying, poorly drained or waterlogged soils. A series of mild winters is especially advantageous to the development of an epidemic. Twig infestations are seldom the cause of a tree's death but often lead to death from other causes. Trunk infestations generally kill a tree in 2 to 3 years. Very low winter temperature, −15° to −30° F., is the most effective control of the insect, such a temperature sometimes causing a complete kill. Predators and parasites are of little significance in controlling the balsam woolly aphid.

Control

Favoring the spruces over balsam fir as suggested under various cuttings (pp. 17 to 22) will help to reduce the insect and disease hazard, except that of the European spruce sawfly. Control of the spruce budworm requires special consideration. Westveld (1946) recognizes two objectives in combating the budworm: (1) abating damage from an impending attack and (2) building up resistance of stands to future attacks. The first objective may be attained by (1) presalvage cutting, that is, cutting of stands containing a high proportion of mature balsam fir, and (2) removal of old defective fir on cut-over land. The second objective may be attained by budworm-resistant cutting methods, which would include favoring spruce and using partial cutting on a 20-year cutting cycle. Limited experimentation indicates that the application of DDT by aircraft may prove an important adjunct to other controls.

The adoption of a rotation of not more than 70 years and the systematic application of weedings and liberation cutting to prevent severe suppression will keep decay at a minimum in balsam fir.

Until other evidence is available, natural controls will have to be depended upon to hold the European spruce sawfly and the balsam woolly aphid in check.

Control of Animal and Logging Damage

The grazing problem in the spruce-fir types is rarely of sufficient importance to demand primary attention. Grazing of cut-over lands during the 10-year period immediately following cutting appears to have practical value in ridding the stand of competing hardwoods and other vegetation that retard the growth and development of young spruce and fir, thereby lessening the amount of cleaning in these young stands (Westveld 1930). Extreme care must be exercised in the application of grazing as a silvicultural measure.

Care and close supervision are the key to eliminating excessive loss of tree growth in logging. Use of less valuable hardwood species for bridge, corduroy, and skidway material, swinging skid trails around instead of through clumps of reproduction, and felling trees into spots supporting the least spruce and fir reproduction, saplings, and poles will eliminate most of the logging damage.

NORTHERN HARDWOOD TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. The three northern hardwood types, described in Table 2, are of great importance in the region, particularly in certain sections of New York and Vermont, where they occupy an extensive acreage (Committee Report 1932).

The original mature forests are uneven-aged, with the classes of mature and overmature trees predominant (Frothingham 1915). The acreage of this class of forest is not large. Second-growth stands, mostly originated after clearcutting but some after abandonment of agricultural land, occupy a large acreage. These stands are predominantly even-aged. A limited area is occupied by uneven-aged stands from which most of the medium-sized trees were removed, thus leaving numerous large veterans. Third-growth forests are generally even-aged and composed largely of sprouts.

Good stocking is in general characteristic of the northern hardwood stands. Very little acreage of cut-over land is denuded of tree growth.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction is usually present in sufficient quantity in ungrazed old-growth timber to provide for a well-stocked new stand.

but the seedlings generally have poor form. Overstocking often causes its growth to be negligible. Farm woodlands are often deficient in advance reproduction owing to destruction of most of it by livestock.

TABLE 2

Description of Northern Hardwood Types

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Sugar maple–beech–yellow birch	Major	High	Deep, fertile, well-drained loams at intermediate altitudes	Sugar maple American beech Yellow birch	American basswood Red maple Hemlock Red spruce Balsam fir Eastern white pine American elm White ash	Climax type
Yellow birch	Minor	Moderate	Deep, fertile, well-drained loams at intermediate altitudes	Yellow birch, sometimes pure	Red maple Sugar maple Paper birch	Temporary, followed by sugar maple–beech–yellow birch type
Sugar maple	Minor	High	Deep, fertile, well-drained loams at intermediate altitudes	Sugar maple, often pure	Yellow birch White ash	Climax type

Sugar maple and American beech are always present in large numbers, and, especially in the denser stands, they frequently predominate. On the better soils white ash and American basswood frequently make up a rather large amount of the advance reproduction. In open stands, yellow birch is usually present in considerable quantity.

Subsequent Reproduction. Reproduction after cutting consists chiefly of seedling sprouts and sprouts supplemented by seedlings that escape injury in logging. All species sprout rather freely and provide a source of reproduction immediately after cutting. In stands where occasional seed trees are left, or even on small clearcut areas, subsequent reproduction from seed usually occurs abundantly. The hardwood species, white ash and American beech excepted, produce seed

in considerable quantity almost annually, thus, yearly the supply of seed for reproduction is ample.

The composition of the subsequent reproduction varies with the age of the stand and the type of cutting applied to it. Clearcutting favors pin cherry, quaking and bigtooth aspen, paper birch, and red maple (Jensen 1943). Moderate cutting creates less favorable conditions for these low-value species. Sprout reproduction is most abundant in the younger stands because younger trees have greater power to coppice after cutting. As a matter of fact, some of the older trees coppice so weakly that many of the sprouts that do originate die within a few years. In general, regeneration of the northern hardwood type is profuse, regardless of the method of cutting (except possibly when clearcutting is applied to a large area of mature or overmature timber), but a desirable composition is not assured unless some attention is given to regulation. Moderate cutting gives the best results in quantity and composition of reproduction, because it controls the seed supply of the better species, it does not create an ideal site for regeneration of low-value intolerant species, and it provides only moderately favorable conditions for the development of coppice growth. Cutting of areas less than 0.6 acres seems to reduce regeneration of such intolerant short-lived species as pin cherry, aspen, and paper birch (Jensen 1943).

Competition. Reproduction of all the hardwoods responds very quickly to the new conditions that are created by cutting. The intolerant species benefit most from the opening of the canopy, however, and unless so provided they die in rather large numbers. The rate of growth of coppice and sucker reproduction is much greater than that of seedling reproduction. Whenever this type of growth is abundant it may offer serious competition to the most valuable seedling growth. The very tolerant sugar maple as well as other tolerant hardwoods are not adversely affected, because they have the ability to withstand severe competition and even though their growth is somewhat retarded, their ultimate survival in the stand is assured. Pin cherry and quaking aspen are the least troublesome; the former is mostly eliminated naturally in 20 to 30 years and the latter in 40 to 60 years (Jensen 1943). Paper birch and red maple are more persistent, but they are mostly eliminated in competition in 80 years. Some of the sprouts of any species become defective at a rather early age when their growth declines and they lose some of their vitality, whereupon they gradually become a less important factor in competing with seedlings.

Windfall. All the hardwood species normally have well-developed root systems; thus, except where a rocky or shallow soil restricts root

development, trees are seldom windthrown. Of the principal hardwood species, yellow birch is the most susceptible to windfall. Windthrow is never extensive, usually uprooting single trees or groups of two or three at widely spaced distances.

Economic Basis

Utilization and Marketing Problems. Profitable utilization of the hardwoods presents no such serious problem in the northern hardwoods as it does in the spruce-fir types. This is because the hardwoods are of good quality and the stands are often accessible to highways or railroads. Portable sawmills and special wood-using industries provide an outlet for a variety of products. The industries often use trees only 6 to 8 inches in diameter. The better hardwoods, such as sugar maple, yellow birch, white ash, and American basswood, are in active demand for saw logs. In a number of localities hardwoods are used extensively for paper manufacture (Cope 1934).

In some sections, particularly in Vermont, sugar maple is used extensively for its sap. The manufacture of maple syrup and sugar has caused many timberland owners to manage their lands primarily for maple-sap production and only secondarily for timber production.

Growth and Rotation. On a site of average productive capacity in Vermont, stands produced approximately 156 board feet per acre annually over a 70-year period (Hawes and Chandler 1914). Growth in thinned and untreated immature stands shows wide variation. In New York, an unthinned stand grew 1 cord per acre annually, while a lightly and a heavily thinned stand grew 1.1 and 1.3 cords per acre annually (Guise 1925). In contrast, a 60-year-old stand in New Hampshire from which approximately one-half the volume was removed in a thinning grew 1 cord per acre annually, while a companion unthinned stand grew ½ cord per acre annually.

The saw-log rotation varies from 70 years on the best sites to 100 years on the poor sites.

Financial Aspects. Data on the financial aspects of silviculture of northern hardwoods are almost entirely lacking.

Application of Methods

The type of reproduction cutting that is most effective depends primarily on the character of the stand, particularly whether it is even- or uneven-aged, on existing markets for small trees, and, to a lesser degree, on the objective of management. The last factor is chiefly important in working out the details of applying the cutting.

Clearcutting and Selection Cutting. Clearcutting is advantageous for stands in which the overstory is chiefly mature and overmature and an understory of younger classes exists (Jensen 1943).

Selection cutting has a place in the management of certain stand conditions. Cope (1946) favors the uneven-aged over the even-aged stand for sugar bush management. The group-selection system is effective in stands that contain groups of promising trees (Jensen 1943). Where good trees are evenly distributed through a stand, uniform selection cutting can be applied. If lumber is to be the main product, cutting should include trees above a variable diameter of 12 to 15 inches d.b.h. However, some of the well-formed, sound trees above this size should be left for quality growth, and the cut should be concentrated in the less valuable species. Where advance reproduction is sparse or lacking, it is usually advisable to leave occasional trees above 15 inches d.b.h. for seed (Dana 1930). White ash, American basswood, sugar maple, and sometimes the birches should be given preference. The birches are worth encouraging where spool or similar stock is in demand. If they are retained in the stand, cutting adjacent to them must be light to prevent their deterioration (Pierson and Nutting 1945, Spaulding and MacAloney 1931). If turnery stock or fuelwood can be marketed profitably, group-selection cutting (clearcutting in patches from ½ to 1 acre), supplemented by improvement cutting, appears to have real merit, because it creates an excellent environment for the development of the reproduction.

Where management as a sugar orchard is the chief objective, selection cutting should be very light; otherwise sap yield will decrease. Sugar maple should be given reasonable encouragement but not to the exclusion of other valuable hardwoods. Supplementary income will be enhanced by the retention of sound, straight trees of American basswood, yellow birch, and, particularly, white ash.

If the timber market will absorb trees as small as 6 or 8 inches d.b.h., even-aged second-growth stands can be most effectively handled by shelterwood cutting. In the absence of a market for the smaller trees, selection cutting, having as its ultimate objective conversion into an uneven-aged stand, is superior.

The first cutting by the shelterwood method should remove not more than 50 per cent of the merchantable volume, most of it from the less desirable species. The removal cutting can be made approximately 10 years later. Cleaning must follow if the most profitable stand is to develop.

Cultural Operations. Although improvement in stand composition can undoubtedly be hastened by cleanings, Jensen (1943) believes that they have doubtful merit because the better species can maintain satisfactory growth to an age of at least 30 years under natural conditions.

Thinning is desirable as soon as potentially valuable trees show a decline in growth rate. Thinnings offer the greatest promise where turnery stock and fuelwood are salable. They should be moderately heavy. When trees of sprout origin must be left, the following principles should be followed: (1) favor sprouts arising from stumps under 4 inches in diameter or, if the sprouts are from larger stumps, favor those of low origin and with small top wounds; (2) favor the most vigorous sprouts in a clump; (3) discriminate against red maple when saw-timber production is the chief consideration; (4) favor single-stemmed over multiple-stemmed individuals; (5) for sprout clumps with high unions, either leave the clump intact or remove it entirely. Stumps should be cut low—1 foot or less in height.

Thinning in young sugar orchards should be aimed at an ultimate stand of 100 crop sugar maples per acre. Trees with well-developed crowns should be selected early, and future thinnings should give them maximum release. Straight, sound white ash and American basswood should also be favored (Hawes and Chandler 1914).

Planting. There is little need for planting when the silvicultural measures previously outlined are properly executed. There are limited areas of denuded and abandoned farm land which can be most effectively rehabilitated by tree planting. Sugar maple, white ash, yellow birch, and red spruce are the most promising species for such lands. A mixture of white ash and red spruce should be profitable on the better soils (Hawes and Chandler 1914). Mixtures should be given preference over pure plantations unless there is definite assurance that the latter will be more profitable. The hardwoods can be planted in spring or fall, the conifers in spring. In mixtures of the two, the hardwoods should be planted before the conifers. Spacing for hardwoods should be 10 by 10 feet; for conifers, 6 by 6 feet.

Slash Disposal

Slash in the northern hardwood types does not constitute a serious fire hazard. The quick dropping of the leaves, rapid decomposition, and the rapid reclothing of the cut-over land by young tree growth which protects the site from desiccation keep inflammability low and

make the period of slash hazard relatively short. Three years after cutting the slash, fire hazard is lowered substantially.

There is no evidence to indicate that slash is either beneficial or detrimental to tree reproduction.

In view of the foregoing, disposal of slash is seldom necessary. Some piling and burning of slash are desirable on limited areas of more than average fire hazard.

Disease and Insect Problems

Ecological Basis

Rot is a menace to nearly all hardwoods at some time during the trees' lives, but there is a difference in the susceptibility of individual trees and species. According to their increasing liability to butt-decay infections, the sprouts of the several species that have been studied fall in the following order: [1] white ash, black cherry, sugar maple, American basswood, paper birch, and red maple. Yellow birch, not included in the study, is generally regarded as highly susceptible to decay. The following relationships are significant in the infection of sprouts by rot and the subsequent rate of spread of the decay: (1) Most of the decay enters either directly from the old stump, or, more generally, through the old stump wound. (2) Decay that enters through dead companion stubs is relatively unimportant in stands under 30 years of age but becomes increasingly important thereafter. (3) The danger of infection grows with increase in diameter or height of the parent stump, because increases in either of these lengthen the time required for the stump wound to heal. If stump wounds of white ash and black cherry are healed before they reach 35 years of age, sugar maple before 30 years, and American basswood and paper birch before 25 years, the decay hazard is low. (4) When the individual stems of a sprout clump develop evenly (have the same height), the decay hazard is high unless cutting is done when sprouts are young, because of the tendency of the stems to form high unions.

Numerous fungi cause decay in hardwoods. Two that are particularly damaging to sprout sugar maple have been reported upon in some detail (Campbell 1939, Campbell and Davidson 1940). One of these (*Daedalea unicolor* [Bull.]) causes canker and decay that work so

[1] Based on *Occasional Paper* 7 of the Northeastern Forest Experiment Station, New Haven, Conn.

rapidly that trees may be weakened enough to be windthrown in 5 to 7 years.

Nectria canker does widespread damage but is most severe at high altitudes (poor sites for hardwoods), in stands containing large proportions of weed species, and in stands that are relatively pure in composition (Grant and Childs 1940). Relative susceptibility of species varies on different sites, but yellow birch is generally the most susceptible, beech the least. Infection may occur on young trees of sapling size. The disease rarely kills a tree outright, but it exposes the bole to infection by wood-destroying fungi that cause serious damage (Spaulding, Grant, and Ayers 1936; Welch 1934).

The *bronzed birch borer* is active where yellow birch and paper birch occur. Damage has been especially severe in Maine since 1944. Apparently any condition that contributes to reduced vigor of these birch trees leads to increased damage by this insect (Pierson and Nutting 1945). Open-grown trees are invariably killed.

Control

Measures for controlling the nectria canker must be varied to meet the needs of each stand or portion of a stand (Grant and Childs 1940). In general, discrimination against weed species and cankered trees (especially those with many cankers) in cuttings and employment of any measures that form and maintain well-mixed, vigorous stands prevent nectria canker from causing serious damage. Control measures should begin at the earliest possible age. When infected trees are cut, they should be removed from the woods and the slash burned. If this is not feasible, girdling is preferable to felling the trees, because trees in contact with the soil fruit heavily (Welch 1934). Where infection is unusually great, only the most severely infected trees can be removed. At high elevations, conversion to conifers may be necessary.

To keep losses from the bronzed birch borer at a minimum careful management of stands containing paper and yellow birch is necessary. Infested trees or stands should be cut as a salvage measure before the wood deteriorates. Trees or stands that are growing slowly should be cut since they represent a high hazard.

Pure stands of birch should be clearcut at maturity. If a heavy cutting of species other than birch must be made in mixed stands, it is advisable to cut the birch at the same time or soon thereafter. If paper birch is a component of a mixed stand, it usually matures earlier than the other species, and it should therefore be cut first.

Wherever sprout reproduction is to be depended upon, stumps should be cut low to insure the development of a maximum number of vigorous trees.

Thinnings should be light and should remove the least thrifty trees.

Control of Animal and Logging Damage

Grazing by domestic livestock cannot be tolerated in the northern hardwood types.

Precautions should be taken, too, to protect trees of large sapling size and larger from damage in logging. Protection of the smaller trees is not necessary since the seedling sprouts that originate from the broken hardwood seedlings develop into superior trees (Jensen 1943).

ASPEN AND PAPER BIRCH TYPES

These types occupy considerable area, but because of their low commercial value they have been given little attention in the research program. They occupy sites that originally supported valuable forests of spruce and fir or northern hardwoods. Reversion to an aspen or paper birch type followed either severe fires or clearcutting. These forests have been studied in more detail in the Lake states region. Although all the results of research on these types in that region may not be applicable to the northeast spruce-hardwood region the author believes that, in general, the results apply. The reader is referred to pp. 332 to 338.

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2 · *New England White Pine Region*

DESCRIPTION AND HISTORY

Location and Landownership

The New England white pine region occupies a belt along the Atlantic seaboard which includes southwestern Maine, southern New Hampshire, southeastern Vermont, eastern and central Massachusetts, and the northeastern corner of Connecticut (Fig. 1). It is limited to low elevations and does not extend inland more than 75 to 100 miles except along the Connecticut River valley, where it reaches inland for a considerable distance in a narrow strip. A detached area that is considered a part of the white pine region occurs around Lake Champlain in Vermont and New York.

The region occupies an area of something like 9,000,000 to 10,000,000 acres, a considerable part of which is not forested. There are no national forests, and it is not likely that the Federal Government will make an effort to establish any because of the difficulty of consolidating areas large enough for efficient administration. Most of the forest lands are in relatively small holdings, many of them farm woodlands. Between 500,000 and 600,000 acres of forest land are state-owned, mostly as state forests.

Physiographic Features

The region is lacking in any pronounced physiographic features, most of the land surface being relatively flat to gently rolling and hilly. Much of the region lies under 500 feet in elevation. The hillier inland sections reach an altitude of 1000 to 1500 feet. The land surface is indented by numerous streams, many of which are large. Extending back from many of these rivers are rather extensive flats that terminate in gently rolling hills.

The soils in general are coarse in texture, sandy loams predominating. Sands and gravels dominate the soils of some sections. The coarser

soils, being well drained, frequently become droughty during the drier seasons of the year. Swamps in which peat or muck is dominant are interspersed through the uplands, constituting in the aggregate a considerable area.

Both large and small rivers as well as lakes are characteristic features of the physiography. Several of the large rivers empty into the Atlantic Ocean. Among the more important of the larger rivers are the Penobscot, Androscoggin, and Kennebec in Maine, the Merrimac running through New Hampshire and Massachusetts, and the Connecticut, draining lower Vermont and New Hampshire. These streams are fed by many tributaries, making an extensive network. Lakes and small ponds are numerous.

Climatic Features

Although this region lies along the Atlantic seaboard, its climate has more the character of a continental than a seaboard climate. Precipitation is abundant and well distributed, temperatures are moderate, subject to frequent changes, and the winter is long and cold.

The precipitation is fairly uniform throughout the entire region, as indicated by the reports of three widely separated representative stations: Keene, New Hampshire, with a mean annual precipitation of 40.13 inches, Worcester, Massachusetts, with 45.12 inches, and Lewiston, Maine, with 45.35 inches (Weather Bureau 1926). Few sections have a lower or higher mean annual precipitation. Moisture is well distributed throughout the year during a normal season. The mean monthly precipitation during the growing season at Keene, New Hampshire, is 3.54, 4.22, 3.59, and 3.61 inches monthly from June to September, inclusively. The driest months, normally April and November, have an average of 3 inches per month. Snow forms an important part of the precipitation during the winter season. Most of it falls between November and April. The average annual fall of snow varies from 50 to nearly 90 inches (Weather Bureau 1926).

Because of its proximity to the Atlantic Ocean, the atmosphere is uniformly moist, relative humidity being high throughout the year. For short periods in summer the relative humidity drops to 30 or 40 per cent. During other seasons it is ordinarily around 70 to 80 per cent.

The climate is characterized by a wide range in temperature from one season to another and by frequent very abrupt diurnal changes. Nearly all stations show that a maximum summer temperature of nearly 100° F. and a minimum winter temperature of from −22° to

−28° F., usually during January, are occasionally reached (Weather Bureau 1926). The mean temperature for the year varies from approximately 44° to 47° F. July, with a mean of 68° to 71° F., is the hottest month. January, with a mean of 18° to 24° F., is the coldest month. A period of approximately 5 months is free of killing frosts, except in the northern sections where it is about a month shorter.

Severe lightning storms are of common occurrence during the summer season, but nearly always they are accompanied by heavy precipitation, which keeps them from being a serious fire hazard.

High winds are fairly usual during the spring, fall, and winter. Although winds of 60 to 70 miles an hour are generally of short duration and local, hurricane winds have occurred, as in 1938. Moderate winds of 5 to 15 miles an hour are common. The prevailing wind direction is northwest except in the summer season, when it is usually southwest.

Development of Lumbering

Lumbering began during the Colonial days but did not attain importance as an industry until early in the nineteenth century, when expansion was rapid. It has been estimated that all the virgin eastern white pine was cut by 1870. Ten years later a considerable quantity of white pine for box and match stock was being removed from second-growth stands. In 1909 the cut of eastern white pine from the state of Massachusetts was greater in proportion to its area than that of any other state in the union (Harper 1918).

Profits from operations in second-growth pine have decreased in recent years because of the competition from the higher-grade softwood lumber derived from the virgin forests of the Pacific Coast and the poorer quality of the remaining local stands. More and more of the second-growth eastern white pine has had to be converted into box board, cooperage, and match stock.

Timber operations are now on a small scale, most of the saw logs being handled by portable or semiportable sawmills. The small size and scattered character of the forest tracts make small operation more practicable. The present production of timber products is inadequate to meet the local demand of the region.

The Effect of Past Practices

The early selective cutting of timber during the Colonial days is primarily of historical interest, because its effects were obliterated by

later practices that were not so conservative. Land clearing for agriculture, particularly active between 1800 and 1830, reduced materially the area of forest. In Massachusetts 50 to 60 per cent of the forest area had been cleared for farming and grazing by 1830 (Cline and Lockard 1925). A few years later farm abandonment was already in progress, many of these areas reproducing naturally to eastern white pine.

Where the land was not cleared for agriculture, cutting became more destructive with each succeeding decade. After 1900 a large portion of the cutting took the form of clearcutting. Fire often followed the cutting. In consequence, species of low commercial value increased in the second-growth stands and the soils deteriorated. Some areas were denuded temporarily, but, where seed trees were not too far removed, new tree growth soon reoccupied the land. White pine, gray birch, and quaking aspen, the seed of which is disseminated long distances by wind, and black and pin cherry, presumably bird-disseminated, reproduced most abundantly on the open sites. The great increase in quaking aspen and gray birch enlarged the food supply of the gypsy moth (Baker and Cline 1936; Behre, Cline, and Baker 1936) and thereby augmented the hazard of damage by this insect.

Where open sites were not soon occupied by tree growth, forest planting was done, notably on lands owned by the states or by privately endowed institutions. The early planting, much of it lacking a scientific basis, increased the acreage of pure stands, particularly of eastern white pine. This practice has made the insect problem more serious than formerly. Recent planting practice has recognized the dangers of pure plantations with the resultant increase in mixed plantations.

THE FORESTS AND THEIR MANAGEMENT

The white pine types, of which there are three, the red oak–basswood–white ash types, and the gray birch–red maple types are the most widely distributed forest types of the New England white pine region. Several others, each confined to a relatively small acreage but in the aggregate constituting considerable area in the region, are merely enumerated here since they are discussed in connection with other regions, where they are more important. The most important of these are: hemlock (see p. 109); northern white-cedar (see p. 347); black ash–American elm–red maple (see p. 107); pitch pine (see p. 100); and red pine (see p. 318), of which four distinct types were recognized (Reed 1926). The artificially established red pine type (usually pure

red pine) is constantly assuming greater importance through extensive planting. Other species planted extensively enough to form local artificial types are Scotch pine, Norway spruce, and European larch. Severe damage has been done to these and other conifers by red squirrels feeding on the lateral and terminal buds during winters of deep snow, apparently because of a deficiency of other foods that are normally consumed (Hart 1936, Hosley 1928).

WHITE PINE TYPES

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of Forest. Table 3 gives essential data on the three white pine types. The white pines form the most extensive and most valuable forests of the region (Fisher 1920). These forests are entirely second growth in all stages of development from seedling to maturity (Dana 1930). Even-aged stands, usually of high density, are characteristic of the white pine type; uneven-aged and even-aged stands, of the white pine–red oak–white ash types; and uneven-aged stands, of the white pine–hemlock types. The more heavily stocked mature stands yield 30,000 to 40,000 board feet per acre.

Stand Regeneration and Development. *Advance Reproduction.* Although the advance reproduction varies with the forest type, the reproduction of all white pine types on the heavier soils has one common characteristic—a small representation of eastern white pine. Pine reproduction, usually in small groups, is confined almost entirely to the openings in the stand where leaf litter is thin and vegetative cover is light (Fisher and Terry 1920). In the white pine and white pine–red oak–white ash types the advance reproduction, generally abundant, is made up largely of tolerant hardwoods. Hemlock, supplemented by the more tolerant hardwoods, sugar maple, and American beech, is the dominant species in the advance reproduction of the white pine–hemlock type (Tarbox and Reed 1924). White pine is often entirely absent.

Subsequent Reproduction in White Pine and White Pine–Red Oak–White Ash Types. It is an established fact that white pine reproduction does not originate from seed stored in the duff (Fisher and Terry 1920). Therefore, there must be a source of seed after cutting if white pine is to reproduce in any of the white pine types, unless cutting is done in the fall of a seed year, in which case abundant reproduction

TABLE 3

DESCRIPTION OF THE WHITE PINE TYPES (COMMITTEE REPORT 1932*a*)

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
White pine	Major	High	Loamy sands and sandy loams, particularly abandoned farm lands, and on very light sandy soils at the lower elevations	White pine usually 80 to 90 per cent	On light soils: Pitch pine, Gray birch, Quaking aspen, Red maple, Pin cherry, White oak; On heavier soils: Paper birch, Sweet birch, Yellow birch, Gray birch, Black cherry, White ash, Sugar maple, American basswood, Hemlock, Red oak	A long-lived temporary type on the loamier soils followed by various hardwood combinations; a permanent type on the sandier soils particularly if cut selectively
White pine–red oak–white ash	Major	High	Frequently follows old field white pine type on soils of medium quality	White pine, Red oak, White ash, Red maple	American basswood, Yellow birch, Bigtooth aspen, Sugar maple, American beech, Paper birch, Black cherry, Hemlock, Sweet birch	A relatively permanent type on the moderately fertile upland soils and less-protected aspects. Clearcutting increases the proportion of pine, oak, and low-value species; conservative cutting favors hemlock and more tolerant hardwoods
White pine–hemlock	Minor	Moderate	Sandy loams in ravines and on north slopes; also to some extent on very light sandy soils	White pine, Hemlock	Small amounts of American beech, sugar maple, American basswood, red maple, white oak, black cherry, yellow birch, white ash, paper birch, red oak, chestnut oak, yellow poplar	Near climax but usually followed by northern hardwood or hemlock type

may follow if leaf litter is thin or absent. White pine produces a considerable quantity of seed every few years after it is 40 to 50 years old, but unless the seed falls on a suitable seed bed, reproduction fails. Cary (1936) has suggested that fire properly used may aid in the establishment of white pine reproduction on certain sites, but there is no experimental evidence to substantiate his theory.

Photograph by Harvard Forest.

Fig. 10. The first cutting by the shelterwood method in a white pine stand. The first cutting should ordinarily remove 50 to 60 per cent of the merchantable volume.

A dense overstory of trees or a heavy understory of shrubs or hardwood seedlings or sprouts precludes the establishment of white pine seedlings on any type of soil. By proper cultural methods, temporary control of the vegetation in both the overstory and understory can be accomplished sufficiently well to allow white pine seedlings to become established on all types of soil. However, on the fine-textured soils, control of the understory vegetation cannot be maintained long enough to permit high survival and proper development of the pine seedlings. Partial cutting, either in the form of the selection or shelterwood method (Fig. 10) has resulted in satisfactory regeneration of white pine on all types of soil, but on heavy soils (principally loams) cuttings that leave little or no overhead protection (clearcutting or seed-

tree cutting) fail to result in an adequate stand of pine seedlings (Fisher and Terry 1920).

On light soils (chiefly loamy sands and gravels) ground cover may become a serious obstacle to the establishment of white pine seedlings. A thick mat of blueberry, which practically precludes the establishment of pine reproduction, develops when the stand is opened by cutting. However, if the openings are kept small—possibly not exceeding 50 to 75 feet in width—this objectionable ground cover may be controlled reasonably well (Lutz and Cline 1947). Scattered low-lying slash in shaded openings encourages the establishment of *Hypnum* moss, which in turn favors the establishment of white pine seedlings. Smith (1940), working in a different part of the region than the previous investigators, found on light soils that a site covered by a partial canopy of approximately 50 per cent was a more favorable environment for survival and early establishment of white pine seedlings than either a site covered with a full canopy or a completely exposed site. Soil moisture was critical under the full canopy, whereas high soil temperature was a major factor in seedling mortality on the exposed site whenever the seedlings were exposed to direct insolation. On the same sites, Hawley (1936) found that systematic light thinnings over a period of 30 years resulted in the establishment of an abundance of white pine seedlings and small quantities of hardwood and hemlock seedlings.

Hardwood Competition. On light soils, white pine encounters no difficulty maintaining itself, because hardwoods generally are not numerous and they are not strong competitors owing to the dryness of the sites (Lutz and Cline 1947). Oaks are the most troublesome to the pine because of their widespreading crown habit. Aspen, gray birch, and pin cherry are the least troublesome because they are intolerant and short-lived.

On medium soils, white pine seedlings compete fairly effectively with hardwood seedlings because the sites are only moderately favorable to vigorous growth of the latter. Especially if cultural treatment aims at groupwise arrangement of pine, this species will constitute a substantial portion of the stand.

The heavy soils are so favorable for rapid growth of hardwoods that, even when frequent cultural treatments are applied to rid the stand of them, the survival of pine seedlings is very low (Lutz and Cline 1947). Better results were secured in pine survival when thrifty 3- or 4-year softwood transpants were planted after clearcutting, but the cost of favoring the pine is exorbitant. The young stands on these

heavy soils are destined to be made up of hardwoods, and they should, therefore, be considered as a part of the red oak–basswood–white ash type (Fig. 15).

Subsequent Reproduction in the White Pine–Hemlock Type. An abundant seed supply and protection by means of an overhead canopy are essential to subsequent reproduction of white pine and hemlock. A dense stand of advance hardwood reproduction or a thick layer of needles such as characterizes many white pine–hemlock stands interferes with the establishment of white pine seedlings, the latter condition usually just temporarily because the litter decomposes gradually after cutting, particularly if the canopy is opened substantially, thus creating a more favorable seed bed for reproduction. Since hardwoods are generally present as advance reproduction or become established readily after cutting, there is always a substantial number of hardwood seedlings in the young growth.

Hemlock, generally regarded as a slow-growing species, actually grows faster, when in a free position, than eastern white pine up to an age of at least 35 years. The hardwood components outgrow white pine even longer, up to 45 years of age. Obviously the pine is at a distinct disadvantage and cannot survive in substantial quantity unless it is freed of competition in the early years of its life.

Hemlock is very tolerant, and, therefore, it can withstand long periods of suppression, during which growth is extremely slow. It can develop in the understory to form a nucleus for a new crop when the main part of the stand is removed. Upon release these understory hemlocks grow more rapidly than trees that have grown in an open position throughout their life; in some cases diameter growth is increased by more than five times as a result of the release (Marshall 1927).

Windfall. Although windfall and windbreakage generally do not account for serious damage in white pine stands, locally the damage may be heavy. If partial cutting is applied to dense old field mature stands, windfall loss may be high.

Economic Basis

Utilization and Marketing Problems. Discussion here will be limited chiefly to eastern white pine, since under good forest management this is the major species of the white pine types. The utilization of the hardwoods is discussed in connection with the northern red oak–basswood–white ash type (p. 67). The facts relating to this hardwood type apply, in general, to white pine types.

The superior value of white pine as a timber tree in the virgin forests does not apply to white pine from second-growth stands. Second-growth pine is generally small and very knotty and, therefore, of low quality. This fact would not be so serious as it is, if all timber in the United States were of similar quality. But the virgin forests of the western regions yield superior lumber, a considerable quantity of which reaches the eastern markets. Therefore, inferior white pine is not readily marketed except for such low-value products as box board, cooperage, and match stock. If the growing of white pine is to be profitable, the timber must be of high quality.

White pine of a relatively small size can be utilized profitably for saw logs. A study of six logging operations demonstrated that lumber could ordinarily be cut profitably from trees 10 inches d.b.h. and over and from logs 8 inches in diameter and larger (Jensen, Behre, and Benson 1940). However, the size of the marginal tree varied widely with several factors—from 6 to 15 inches for trees and 5 to 10 inches for logs.

Producing Quality White Pine. Number and size of knots, both of which can be artificially controlled, affect the quality of white pine lumber. Mixed stands such as the white pine–red oak–white ash and the white pine–hemlock types yield a somewhat higher quality of pine timber than do pure pine stands. Natural pruning in the mixed stands generally is more effective than in pure stands. An examination in stands from 20 to 90 years old on the Harvard Forest showed the average size of knots on white pine in mixed stands to be approximately one-half as large as in pure stands (Tarbox and Reed 1924).

In the white pine type dense stands encouraged the production of high-quality wood by reducing the damage caused by the white pine weevil (Gevorkiantz and Hosley 1929) and by killing the lower limbs when they have a small diameter; e.g., on site II in a 20- to 30-year-old white pine stand the diameter of the knots varied from 0.33 inch where there were 3000 trees per acre to 0.79 inch where there were 500 trees per acre. Density of the stand has added significance in that the crowns of trees in open stands are often broken, thus decreasing the size of the crown and, in turn, the rate of growth.

In white pine–hemlock stands the quality of white pine is best where the individual pines are completely separated from one another by hemlock.

The quality of white pine lumber can be improved also by artificial pruning of small trees, preferably under 4 to 5 inches in diameter (Cline and Fletcher 1928).

Demand for Products. Industries that utilize white pine are numerous. The wooden-box industry is the most important small woodworking plant in the market for white pine. The pail and woodenware industry are next in importance, followed by the match industry, which at present is of minor importance. All these can utilize such small trees as may be removed in thinning.

A complete network of hard roads and railroads facilitates transportation throughout the region.

Growth and Rotation. The growth of eastern white pine is influenced by stand composition and density. Pure, unthinned stands of white pine make rapid growth in early life but fail to maintain this growth rate in later life (Cline and Lockard 1925), as was the original belief (Fenska 1922). This later, slower growth is due to excessive crown friction, which can be reduced by timely thinnings. Decreased rate of growth may carry over into succeeding rotations because of soil deterioration, if practically pure stands are perpetuated (Griffith, Hartwell, and Shaw, 1930). Faster growth and improved quality of white pine in mixture with hardwoods are offset to some extent by lower yields, owing to the inherently slower growth of hardwoods.

That thinning definitely stimulates growth is demonstrated by Hawley's studies of white pine stands on sandy soil. Six thinnings, over a period of 30 years, each removing approximately 15 per cent of the board-foot volume, gave only slightly greater growth in board feet annually. More significant, however, are the facts that the average diameter was increased by nearly 4 inches and that the proportion of board-foot volume in trees over 10 inches d.b.h. increased from 63 to 97 per cent of the total volume (Hawley 1936). Acceleration in growth is greatest with the heavier thinning (Hawley 1927).

The usual length of rotation for pine stands is between 60 and 80 years, varying with the site and composition of the stand (Baker and Cline 1936, Fenska 1922, Spaeth 1920); but where site and stand quality are high longer rotations may prove more profitable.

Financial Aspects. *Cultural Operations.* Information from various sources indicates that cultural operations in the forms of cleaning, thinning, and pruning in white pine stands are profitable. According to Spaeth (1922), release cuttings applied at the critical time may change the yield of certain white pine stands from 54 cords of inferior fuelwood to 30,000 board feet of white pine in a 60-year rotation. The investment in cleanings ranges from 3 man-hours per acre per operation on light soils to 5 to 7 man-hours on medium soils (Lutz and Cline 1947). Since two to three cleanings must be applied to

most stands, the cleaning investment generally is between 6 and 20 hours per acre. Fisher estimated that the increased income from a stand at 60 years resulting from cleaning would be more than forty times the investment in cleaning (Fisher 1918, Fisher and Terry 1920).

Early thinnings and improvement cuttings ordinarily cannot be made at an immediate profit. Hawley (1936) estimates that the first three thinnings over a period of 15 years and beginning at an age of 15 years do not pay for themselves. However, where hardwoods occur in mixture with the pine, the early thinnings may yield a net profit, because small hardwoods can be sold to better advantage (Hawley and Clapp 1942). Thinnings after 30 to 40 years can be made at a profit.

Pruning. Artificial pruning, when done judiciously, is regarded as a profitable operation. In Massachusetts when the initial investment carried at compound interest to the end of the rotation amounted to \$11.04 (on trees with a knotty core of 7 inches), the net loss was \$1.21 per thousand board feet, but when the initial investment amounted to \$2.76 at the end of the rotation a net profit of \$16.57 per thousand board feet was realized (Cline and Fletcher 1928). Profits from pruning have been estimated at as much as \$35.00 per thousand board feet. Apparently, when pruning cannot be done at a rate of at least 75 linear feet per man-hour, the cost is too high to justify the investment.

Pruning and thinning to reclaim severely weeviled pure open stands of white pine cost \$15.00 to \$18.00 per acre (Cline and MacAloney 1931, 1935). Whether these costs will be repaid by the increased value of the final crop remains to be seen, but since the untreated stands are apparently practically worthless it seems likely that the work is justified.

Selection vs. Clearcutting. Data on the costs of natural regeneration under different methods of cutting and on the relative profitableness of different methods of cutting are meager. Cline (1924) cites one case of greater profits from group-selection cutting than from clearcutting in which the landowner in 23 years quadrupled his investment by selection cutting while he fell somewhat short of doubling it by a clearcutting.

When hardwoods constitute up to 50 per cent of a pine stand, estimates indicate that the gross return is approximately the same as that from a stand composed wholly of pine (Cline and Lockard 1925). When the hardwood component exceeds 50 per cent, returns are likely to fall off.

Application of Methods

The soil must be regarded as a major factor in the results that may be expected from different silvicultural practices. On light soils stands can be made to contain a maximum quantity of white pine, on medium soils it is generally costly to attempt to develop a stand composed of much more than one-half white pine, and on heavy soils it is unwise to try to encourage the white pine.

All silvicultural methods should include consideration of the previous history and condition of the stand, markets, and character of the soil.

Shelterwood Cutting. If the tree crowns have not been unduly reduced in size by old age or overstocking, the shelterwood method of cutting is the most satisfactory method on soils of more than average productivity where reproduction is lacking. The seed cutting should be made when the ground is bare in order that the soil will be scarified by the logging. The first cut should remove 50 to 60 per cent of the canopy, leaving in the reserve stand the better dominant and codominant trees (Fig. 10). The second and final cut should be made 4 to 10 years after reproduction becomes established, at which time the seedlings can withstand the exposure (Hawley and Clapp 1942) (Fig. 11).

Stands on any kind of soil which have been thinned systematically support an abundance of reproduction and therefore do not require a seed cutting. For sandy soils, it is advisable to follow Hawley's suggestion (1936) that a removal cutting taking out 40 to 60 per cent of the volume be applied 5 years before the final cutting in order to improve the vigor of the seedlings. This preliminary cutting seems to be necessary on the heavier soils also. Just before the final cutting on the better soils, all advance growth of hardwoods (these have poor form because of suppression) should be cut back to permit their development of well-formed stems, and shrubs should also be cut back to reduce competition.

Clearcutting. Clearcutting should be used in old stands which have grown so dense that the success of reproduction is imperiled by poor seed production from the small-crowned trees or by windfall (Hawley and Clapp 1942). In such stands regeneration has to be secured by planting, which should be delayed until two seasons after cutting in order to avoid damage by the pales weevil (see p. 62).

Open-grown stands that are of low quality can best be handled by clearcutting, also. If the annual cutting areas are kept small enough,

such stands can be reproduced naturally. They can, however, be regenerated also by planting. The competition from hardwoods must be combated by transplants (Cline and Lockard 1925).

Selection Cutting. In uneven-aged white pine stands on sandy soils selection cutting is recommended. The cut should be as light as is

Photograph by Harvard Forest.

FIG. 11. Eastern white pine reproduction resulting from shelterwood cutting. Such stands are even-aged.

economically feasible and should not exceed 50 to 60 per cent of the merchantable volume of the stand (Dana 1930). Openings in the canopy should be kept small, preferably not exceeding 50 to 60 feet in diameter. If there is a deficiency of young trees of seed-bearing size, several of the older pines should be retained for seed.

Heiberg (1942, 1945) advocates basing the selection of trees in partial cuttings on the ability of the tree to yield a satisfactory interest return. That his premise has merit is evidenced by the fact that he was able to secure growth of 809 board feet per acre annually over a 5-year period by following this system.

Cleaning. Cleaning must have the objective of producing the most valuable crop possible and minimizing damage to the stand by the white pine weevil and the gypsy moth (the latter is generally a minor factor in pine stands). This objective implies the retention of a reasonable number of valuable hardwood species that are not favored food species of the gypsy moth and the leaving of an adequate number of hardwoods to minimize white pine weevil damage. On the sandy soils it is not advisable to allow hardwood species to constitute more than 15 to 25 per cent of the stand, whereas on the better soils hardwoods may make up 50 per cent or more of the stand.

Cleaning is recommended for all young stands. The number of cleanings depends on the facility with which the crop trees can be placed in a free position—a matter that can be determined only on the ground as the stand develops. The general plan in making cleanings should be (1) to select the final crop trees of desirable species and form, (2) to cut all trees that overtop or will overtop the crop trees before the next cleaning is made, and (3) to leave subordinate trees of slow growth for pruning and protection. In any stand in which hardwoods are to be encouraged the pine should be developed in groups independent of the hardwoods, these groups being 30 to 75 feet in diameter (Cline 1929) (Fig. 12).

The first cleaning, 3 to 8 years after the final removal cutting, must usually be followed by one or two additional cleanings 2 to 5 years apart. In the pine groups, only those hardwoods completely overtopping the pines should be cut. All other hardwoods should be left for protection from the white pine weevil. In the hardwood groups, the selection of hardwoods to be favored should be based on site adaptability, economic value, and susceptibility to attack by the gypsy moth. Such hardwoods as white ash, sugar maple, and yellow birch combine high commercial value and low susceptibility to the gypsy moth. There is little danger in leaving paper birch and red oak when the proportion of hardwoods is small. Along the edges of the white pine groups, preference should be given to such small-crowned species as white ash, black cherry, and the birches as crop trees. Retention of hardwoods that are not interfering with crop trees is desirable as protection against the white pine weevil.

Applying cleanings in summer is advantageous because competition among trees can be judged more accurately when the hardwoods have their leaves than in the dormant season. With some species summer cleaning has the added advantage of reducing the amount of sprouting of the cut trees.

Thinning. If three cleanings were made in a stand, the last one is applied when the stand is 15 to 20 years old. In many such stands, the first thinning can be postponed until the pine yields commercially profitable products—at an age of 30 to 40 years. For stands that are managed less intensively during the first 15 to 20 years, a noncommercial thinning may be necessary between the tenth and twentieth

Photograph by Harvard Forest.

FIG. 12. A mixture of eastern white pine and hardwoods can be grown successfully on the better soils. Pine groups can be 30 to 75 feet in diameter.

years (Hawley and Clapp 1942). Hawley (1936) recommends low thinnings that remove 15 per cent of the volume at 5-year intervals. Some foresters are of the opinion that, where pruning is applied to selected trees, the first and possibly the second thinning might better be high thinnings in order that the pruned trees may get more release.

Pruning. Pruning can be applied advantageously to stands containing well-developed stems on the better soils. Except on the best soils, where it may be necessary to start pruning at an early age because of rapid growth, pruning can be best done at the time of the first thinning (Cline and Fletcher 1928) (Fig. 13). The first pruning should remove the limbs to a distance of approximately one-half the height of the tree, i.e., 5 to 7 feet. Two or three prunings, each following the principle of the first, will produce a clear bole to a height of 16 to

20 feet. The pruning should generally be limited to 75 to 100 carefully selected trees per acre. The pruned trees should be given every consideration in future thinning operations.

Photograph by Yale School of Forestry.

Fig. 13. Pruning of crop trees which should begin when the trees are 2 to 4 inches d.b.h. will increase the quantity of high-quality white pine lumber at a small investment in labor.

Severely weeviled white pine stands, such as occur where early control was not applied, may be given special treatment in the form of pruning and thinning. Trees to be pruned should be carefully selected from the best trees, which, in badly weeviled stands, often are in the codominant and intermediate crown classes. Thinning, accomplished by girdling the overtopping dominant trees, should be done at the time of pruning (Cline and MacAloney 1931). If the codominant and

intermediate trees exceed 5 inches in diameter, pruning should be dispensed with and only the girdling should be applied. Two or three pruning and girdling operations are needed to put these stands in satisfactory shape.

Pruning should generally be restricted to limbs 1½ inches and under in diameter, and when limbs over 3 inches must be removed the wounds should be coated with a mixture of dry Bordeaux and linseed oil in equal parts to prevent infection by *Stereum sanguinolentum*.

Planting. Forest planting should figure in the silviculture of the white pine type on abandoned farm land, much of which is admirably suited to the production of white pine, and in understocked mixed stands where it is desired to increase the proportion of white pine. In view of the different varieties of damage suffered by this species and the deterioration of the soil in pure stands of white pine, it cannot be urged too strongly that this tree be planted with discretion (Fisher 1928). Furthermore, planting costs can be materially reduced by utilizing the established hardwoods as a part of the stand. Much the same objective has Stafford's suggestion (1931) of planting 300 trees per acre, which would be the final crop trees, in what he refers to as "skeleton planting." Although this method undoubtedly has merit, the author believes that often the apparent low cost would not materialize or the stand would not be properly stocked owing to the hardwoods' failure to "fill in" satisfactorily.

Although mixtures of hardwoods and white pine appear to be best for wide application, other mixtures, particularly white pine and Norway spruce, have merit. The white pine–Norway spruce mixture, although having some disadvantage from the standpoint of weevil damage, has possibilities on the better soils (loams and sandy loams) in localities where pulpwood can be marketed profitably (Hosley 1936). Three-year white pine seedlings and 2-year Norway spruce seedlings or 3-year (2-1) transplants are recommended for areas supporting very little vegetation. Where tree cover or other vegetation is abundant, 4-year transplants of both species should be used. Norway spruce can also be planted advantageously in mixture with hardwoods (Hosley 1936).

Red pine is gaining favor as planting material. It can be planted on a variety of sites but should not be used in the higher, more exposed locations where it suffers from ice injury. On such sites, Norway spruce is preferable.

Red pine should be spaced 8 by 8 feet. Other species may be planted 6 by 6 feet. A notable exception is in the planting of white pine on

open fields or pastures, where a spacing of 5 by 5 feet is necessary as a preventive to serious weeviling. Spring is the best season for planting, except on the sandy soils, where fall planting will give equally good results.

Slash Disposal

Slash in Relation to Fire

The slash of eastern white pine is much more hazardous than that of other species in the white pine stands. This is due to its resinous character, the slowness with which the needles drop, and its slow decomposition. The hazard is not completely gone for at least 12 years after cutting. Hemlock slash decomposes somewhat faster. Hardwood slash is only slightly dangerous after 4 or 5 years. The slash hazard is greatest on sandy soils because of the dryness of the site and the preponderance of white pine in the stand. The degree of danger of any area is closely related to the proportion of white pine slash and the area's location in relation to roads. Fire hazards are greatest along roads (Hawley and Clapp 1942).

Ecological Aspects of Slash

The meager data available indicate that heavy accumulations of white pine slash are adverse to the establishment of reproduction but that such accumulations occur so rarely that, in general, white pine slash does not interfere with the establishment of a well-stocked stand of reproduction (McKinnon, Hyde, and Cline 1935). On the other hand, a light cover of low-lying slash in shaded areas on light soils can be beneficial to the establishment of white pine seedlings (see p. 47). Hardwood slash rarely interferes with reproduction.

Economic Considerations

Windrow-burning of slash can be accomplished for one-sixth to one-third the cost of piling and burning or swamper burning. Where utilization is close and forest tracts are small and surrounded by farm land, it is doubtful whether expenditures for complete disposal by any of these methods would be a sound financial investment.

Application of Methods

Disposal of slash should be limited to white pine slash. Complete disposal is most important where slash is heavy enough to interfere with the regeneration of white pine or where the fire hazard is high.

as along roads. Piling and burning or swamper burning must be used wherever partial cutting is employed, windrow-burning may be used where clearcutting is applied. The disposal of slash by burning must be most complete in stands composed chiefly of pine and in areas adjacent to roads.

Disease and Insect Problems

Ecological Basis

Insects and diseases play an important role in the development of white pine stands from the time the seedling first emerges from the soil to maturity. The most critical period, however, is during the first 25 to 30 years, when the white pine weevil and the pales weevil are most active. The gypsy moth, white pine blister rust, and rots are other sources of damage.

The destruction wrought by the *pales weevil* was not fully recognized until 1913 when Carter reported damage to 61.7 per cent of the white pine transplants during the first growing season (planted on a newly cut-over area), 9.5 per cent of them being injured beyond recovery (Carter 1913). Although other species of coniferous seedlings are attacked by the pales weevil, the weevil's favorite food is white pine seedlings under 3 feet in height. The resinous odor emanating from freshly cut stumps, slash, or lumber attracts the weevils (Fisher and Terry 1920, Miller 1934, Reed 1926). The insect is most active during the first 2 years after cutting, as much as 98 per cent of the damage occurring during this period (Miller 1934). Unless reproduction is abundant, a stand of seedlings may be completely destroyed by the girdling caused by the insects feeding on the bark.

White pine reproduction that escapes the pales weevil often is not free from menace for long, because the *white pine weevil* frequently begins working in reproduction stands 4 years after their establishment and seldom postpones its initial attack until as late as the 7th year (Graham 1926, Maughan 1930). The many studies of this insect, scattered throughout the region and outside it, lead to much the same conclusion (Belyea 1923, Cline and MacAloney 1931, Committee Report 1932, Graham 1918, Graham 1926, MacAloney 1930. Maughan 1930, Peirson 1921, 1922). The weevil attacks the current year's terminal shoot or leader of white pine, causing its death, which leads to forking or crookedness and causes a loss of height growth (Fig. 14). Composition and density of the stand influence the degree

Photograph by Harvard Forest.

Fig. 14. Frequent attacks by the white pine weevil, common in open stands, causes such deformity and abnormal branch development that only poor-quality white pine timber is produced.

of damage, the damage being greatest in pure open stands of white pine (Dana 1930). The white pine–red oak–white ash and white pine–hemlock stands are therefore less susceptible to attack than white pine stands. Except for one study, from which the authors concluded that 1500 to 1800 trees per acre are needed to develop a density high enough to prevent excessive damage (Peirson 1922),[1] the general conclusion has been reached that 1200 to 1500 trees per acre evenly distributed will create a stand of sufficient density to prevent serious injury by the weevil (Graham 1926, Maughan 1930).

Unfortunately the best trees of a stand are attacked most severely. Cline and MacAloney (1931) found in Massachusetts that trees in the codominant and dominant crown classes were two and three and one-half times, respectively, as subject to severe damage as trees in the intermediate crown class. With the exception of the poorest sites (site III for white pine), the older existing plantations, mostly understocked, contain, in spite of the weevil damage, enough white pine trees of sufficiently good form to provide, if released, for an adequate number of crop trees (Graham 1926, Maughan 1930).

Experience demonstrates that the form of the infested trees can be improved and the subsequent amount of weeviling can be greatly reduced by control measures (described p. 63) applied to every infested tree (Maughan 1930). Partial control measures are regarded as unsatisfactory. Complete control measures may be expected to reduce the damage by approximately 40 and 50 per cent, respectively, during the second and third years after treatment, whereas untreated areas will show increases in number of weeviled trees of approximately 60 and 40 per cent, respectively, during these years.

White pine stands are low in susceptibility to attack by the *gypsy moth* (see p. 70 for discussion of factors affecting susceptibility). If badly abused or surrounded by susceptible types, defoliation may occur (Bess, Spurr, and Littlefield 1947). The occurrence of gray birch in white pine stands increases its susceptibility (see pp. 70 and 71). The foliage of white pine and hemlock is not eaten by the young gypsy moth larvae, but it is highly favored as a food by large caterpillars. A single defoliation of pine or hemlock is usually fatal (Behre, Cline, and Baker 1936).

White pine blister rust, a disease that attacks white pine trees of any age, has been firmly established here for many years. Its perpetuation depends on the presence of currant or gooseberry bushes in

[1] A. C. Cline is of the opinion that this density is necessary to prevent damage wherever infestation is likely to be heavy.

the immediate vicinity. Trees that are attacked are doomed to a slow but certain death; therefore, it is of vital importance that infection be prevented.

Rot-producing fungi are of minor importance, occurring chiefly in hardwoods of sprout origin. A dangerous fungus, *Stereum sanguinolentum* (see p. 57), has been observed gaining entrance into the bole of white pine of which limbs over 3 inches in diameter had been removed in pruning.

Economic Basis

Financial considerations are involved only in the control of the white pine weevil and the white pine blister rust because the other pests are controlled by special silvicultural measures that do not increase the cost of growing the timber crop. The adoption of partial cutting and natural reproduction methods should eventually reduce the cost of weevil control to a negligible amount. Where silvicultural control of the white pine weevil has not proved effective, other controls must be considered. If infestation is very heavy, the cost of other methods of control may be prohibitive. In pure well-stocked white pine stands in sections of light-to-moderate infestation, cutting and burning of infested tips has been done at a cost of $0.60 per acre per year for 8 years, or approximately $5.00 per acre (Maughan 1930). More recently, effective control has been secured by spraying at a cost of $2.00 per acre for a single spraying (Potts, Cline, and McIntyre 1942). Since this method has not been used sufficiently long to establish the number of sprayings that would be needed, the total cost is not known. The advocates of this method point out that the wider spacing which can be used in planting when spray is the means of control is an economy in the overall cost of producing white pine.

The average cost of the initial work to control the white pine blister rust has been $0.21 per acre (Dana 1930), ranging from $0.10 to $2.00. Subsequent work is estimated to be cheaper. The results amply justify the cost.

Control Methods

Control of the damage by the pales weevil must depend on the method of regenerating the stand. If dependence is to be placed on planting, then control of damage must be based on properly timed planting, which means postponement of planting until the third season after cutting. If natural reproduction is to be the origin of the new

stand, then reproduction must be overabundant or mostly over 3 feet tall. Judicious cuttings in the later years of the rotation should result in either the establishment of overabundant reproduction or the development of tall reproduction (i.e., over 3 feet tall), or it may accomplish both. Which it accomplishes depends on whether there is any reproduction on the ground at the time of the cutting and on the length of time that elapses between the first and second cuttings.

The emphasis in control of the white pine weevil should be placed on silvicultural methods that minimize weevil infestation—accomplished through effective control of stand density and composition. The adoption of this principle will make artificial control of decreasing importance in the future. For natural stands, this means partial-cutting measures that will insure abundant reproduction, followed by stand-improvement measures that will encourage some hardwoods in the stands. For plantations, no fewer than 1200 well-distributed trees per acre should be the objective. Groupwise mixtures should be encouraged. Hardwoods should be given preference over other conifers in mixture with white pine. If conifers are planted, species that grow faster than white pine are preferable; but, if species of equal or slower growth than white pine are used, they should be planted a few years in advance of the white pine (Committee Report 1932*b*).

If weeviling develops in spite of prevention measures, artificial control is desirable but has economic justification only on the better sites in stands that have only light-to-moderate infestation. An analysis of recommended control measures (MacAloney 1930, Maughan 1930) leads the author to a recommendation of the following as one of the most practical measures. At the first evidence of weevil damage, weeviled tips should be cut and burned *annually*. Cutting should be postponed until the weeviled tips wither and turn brown (in Connecticut this occurs during the first or second week of July), thereby often making a second cutting unnecessary (Maughan 1930). The cut should be made at the whorl of branches just below the lowest evidence of any larval activity—generally involving the removal of 2 years' growth. Complete burning of all tips is essential. Control should be continued as long as the tree terminals can be reached conveniently. The treated trees should be favored in subsequent thinnings to promote rapid growth.

Since spraying has not had sufficient trial to demonstrate its long-time effectiveness, it is merely suggested as a promising possibility. Leaders and bark should be sprayed thoroughly in late March or during

April with a spray composed of 1 part lead arsenate, 10 parts water, and 0.3 part adhesive oil at a rate of 5 gallons of spray per acre (Potts, Cline, and McIntyre 1942). Frequency of spraying has not been determined, but apparently annual treatments are not necessary. Spraying should begin as soon as the trees become attractive to the weevil—usually when they are about 6 years old.

DDT as a spray shows promise but research has not gone far enough to be conclusive on dosage or frequency of application. It appears that the application of less than three pounds of DDT per acre is not effective.

Control of the gypsy moth in white pine stands can be accomplished at little expense by simple measures. Wherever gray birch is an important component of the stand and the stocking of white pine is adequate, the removal of the gray birch is the best insurance against the gypsy moth. Weeding to favor white pine and the resistant hardwoods (see p. 70) is effective on the poorer sites. On the better sites, this practice is not feasible because the frequent weedings that are necessary are too costly. The maintenance of well-stocked stands is good insurance of protection against gypsy moth as well as white pine weevil.

Control of the white pine blister rust can be accomplished by eradication of all European black currant bushes and of the bushes of all other species of currant and gooseberries (except the cultivated red currant, which need not be eradicated) within 900 feet of any white pine stand (Snell 1941). The bushes must be completely pulled up to prevent subsequent sprouting (Dana 1930). Systematic inspection and re-eradication are essential to satisfactory control within areas of known blister rust infection (Hirt 1939).

White pine stands can be made relatively free of rot by systematically removing hardwoods of sprout origin in the various cultural operations.

Control of Animal and Logging Damage

There are no special problems in the control of animal and logging damage in the white pine types. In general, livestock should be kept out of the woods.

All trees of sapling size and larger should be carefully protected during logging. Swamping out of hardwoods of seedling size is not objectionable because the trees that develop from sprouting are usually superior to the original seedling.

NORTHERN RED OAK–BASSWOOD–WHITE ASH TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest. Spaeth (1920) refers to these hardwood stands as the transition hardwood type. Although the northern red oak–basswood–white ash type is the nearest approach in the standard type classification (Committee Report 1932*a*), the relative importance of the various species in this region does not conform to that given in the outline below. Red maple is actually a major species and basswood a minor species in this region, whereas the abundance of white ash varies widely with the site quality, being most abundant on the better sites. Many of these stands have originated from clearcutting of white pine stands on the better soils (Fig. 15). The type is described as follows:

Importance.
  Area—Major.
  Commercial Value—High.
Sites Occupied—Moist, fertile, deep loams, often resulting from clearcutting of old field white pine on the better soils, or the white pine–red oak–white ash type.
Associated Species.
  Major—Red oak, American basswood, white ash, sugar maple, American beech, yellow birch.
  Minor—Red maple, quaking aspen, paper birch, eastern white pine.
Place in Succession—Semipermanent type with sugar maple and hemlock gradually increasing.

The northern red oak–basswood–white ash forests are even-aged, second-growth stands composed of seedlings, seedling sprouts, and sprouts, the last two usually predominant. They are usually irregularly stocked. Stands of various ages are represented.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction is often sufficiently abundant in stands that have not been grazed by domestic livestock to provide ample stocking for a new stand. Only in the densest stands is reproduction deficient, but even here sugar maple and American beech seedlings are fairly numerous. In the more open stands the more tolerant oaks, American basswood, and white ash seedlings occur in considerable numbers.

Subsequent Reproduction. Many of the seedlings of the advance reproduction are broken during logging and then develop into seedling

sprouts. Sprouts develop from the stumps of the younger trees that are cut; thus, the reproduction is reinforced immediately after cutting. A moderate canopy in which there are numerous seed-bearing trees of

Photograph by Harvard Forest.

Fig. 15. On heavy soils second-growth white pine stands are easily replaced by hardwoods. Northern red oak and white ash will yield high-quality products on such sites.

the more valuable species is the best insurance for an improvement of the composition of the reproduction because the site is then unfavorable to subsequent regeneration of such species as red maple and gray birch. Even though the composition of the subsequent reproduction is controlled reasonably well, there are enough seedlings of the more

aggressive low-value species present in the reproduction stand to cause serious interference with the normal development of the better seedlings within 5 years after cutting.

Effect of Competition. The multiple-stemmed, stump sprouts of gray birch, red oak, and red maple offer the most severe competition, and next the single-stemmed gray birch and red maple (McKinnon, Hyde, and Cline 1935). Pin cherry and the poplars, although growing rapidly, are less troublesome because of their intolerance. Paper birch and sweet birch because of their rapid growth maintain themselves reasonably well in competition with the aggressive species. White ash in early life suffers most of any of the high-value species under unrestricted competition, red oak particularly gaining thereby. Black cherry suffers severely also, more so than the white ash in middle life. Seedlings of sugar maple, yellow birch, and American basswood are at a distinct disadvantage in competition but are sufficiently tolerant to persist for many years. Stands that develop without treatment for more than 30 years are usually composed chiefly of oaks (McKinnon, Hyde, and Cline 1935).

Windfall. Windfall is negligible because all species have extensive root systems.

Windbreakage is generally associated with defect in the bole. Sleet storms occasionally cause damage in open stands or along the edges of stands, numerous limbs being broken out of the tree crowns at such times. Subsequent infection by rot-producing fungi may later lead to windbreakage.

Economic Basis

Utilization and Marketing Problems. The most valuable hardwoods are sugar maple, American basswood, yellow birch, red oak, white oak, and white ash, the last-named generally commanding the highest price. In general, there is little market for gray birch, pin cherry, and quaking aspen, because they do not often grow large, they are defective by the time they attain marketable size, and their mechanical properties are such that they are not adaptable to a variety of uses. In some localities aspen and cottonwood are in demand as excelsior bolts. The market for red maple generally is not good, although occasionally, when sound, it is in demand for saw logs, which sometimes are worth nearly as much as sugar maple logs.

The market for fuelwood, although gradually decreasing, is substantial, especially in the smaller towns and near the large cities.

Even the low-value species are often accepted for fuelwood. Material as small as 2 or 3 inches in diameter can be utilized for this purpose. The market price of fuelwood is often not much more than the cost of its manufacture.

Several of the hardwoods, especially the oaks, are always in demand in the form of railroad ties. In general, railroad ties are not so valuable as the same amount of wood in the form of lumber. The many wood-using industries scattered throughout the region make it possible generally to market good-quality timber advantageously.

Growth and Rotation. To produce high-quality products, chiefly saw logs, a rotation of at least 70 years must be adopted on all except possibly the best sites, where a somewhat shorter rotation may be feasible. Crop trees should be 14 to 17 inches d.b.h. in 60 years, and 15 to 19 inches in 70 years, in stands that are given systematic silvicultural treatment throughout the rotation (Cline 1935).

Financial Aspects. In the majority of northern red oak–basswood–white ash stands, valuable timber crops cannot be produced unless cleanings are applied. Their cost is estimated to be $2.00 to $4.00 per acre for each treatment. Improvement cutting is usually unnecessary in stands that have been cleaned. On the Harvard Forest the cost of two cleanings and one thinning in stands from 17 to 25 years old was $18.20 per acre (28 man-hours at $0.65 per hour), exclusive of supervision calculated at $10.00, or a total of $28.20 per acre (Cline 1935). This treatment, followed by a second thinning at 35 to 40 years, which should yield enough cordwood to pay for the operation, and a third thinning at 45 to 50 years, which should yield a small profit, is expected to increase the final stumpage value of the crop by $400 to $500 per acre.

Data are not available on the financial aspects of other silvicultural operations.

Application of Methods

The type of cutting to be applied to mature stands should be based on the form of stand and the presence of advance reproduction. Even-aged stands, fully stocked with advance reproduction, may be clear-cut; even-aged stands, deficient in advance reproduction, should be cut by the shelterwood method. For uneven-aged stands selection cutting is recommended.

Shelterwood Cutting. The first cutting of the shelterwood method (the seed cutting) should aim at the establishment of a stand of com-

mercially valuable species of low susceptibility to damage by the gypsy moth (see p. 70). Fifty to sixty per cent of the crown canopy, to include a maximum amount of species not wanted in the new stand, and defective trees should be removed in this cutting. The removal cutting can be made 5 to 6 years later, when reproduction is well established.

Selection Cutting. Selection cutting, applicable to uneven-aged stands, should be as light as is economically feasible (Dana 1930). The ultimate objective should be the production of high-quality saw logs. In stands previously unmanaged, this necessitates the removal in the first cuttings of a considerable amount of low-grade material. White ash, sugar maple, and yellow birch should be encouraged in the reproduction. White and red oak and American basswood can be favored to the extent that they constitute not over 50 per cent of the stand (see p. 71).

If good seed trees are scarce among the younger trees, the retention of an occasional mature tree may be necessary to make ample provision for reproduction.

Within financial limitations, tree selection should be based on silvicultural needs of each individual part of the stand.

Cleaning. Cleanings must be an integral phase of the treatment of all young stands. Particular attention should be given to controlling the stand composition in such a way that it will be immune to serious damage by the gypsy moth. The first cleaning should be done preferably before the stand exceeds 5 years of age. The frequency and intensity of the cleanings have to be gauged by the abundance of the more aggressive low-value species. The more abundant they are, the more frequent and intensive must be the cleaning. Two or three cleanings take care of the majority of stands adequately. Stump sprouts of all species should be discriminated against in favor of seedlings or seedling sprouts of the more valuable species (McKinnon, Hyde, and Cline 1935).

Thinning. Thinnings must follow the cleanings. They can usually begin soon after the twenty-fifth year in stands previously cleaned, and continue at intervals of 10 years or less until the stand is ready for the reproduction cutting. In these operations, as in all others, the more valuable species of low susceptibility to the gypsy moth should be favored.

Planting. Planting does not seem to have a place in the silviculture of the red oak–basswood–white ash type.

Slash Disposal

Any treatment of the slash, other than that accomplished by close utilization, is unnecessary, because the slash of the species most resistant to decay is no longer a serious fire hazard after 3 to 4 years, even though complete decomposition requires 8 to 10 years, and slash has no apparent detrimental effect on reproduction.

Disease and Insect Problems

Ecological Basis

The *gypsy moth* is the greatest insect menace of the northern red oak–basswood–white ash type. This type is relatively resistant, but many of the types with which it is associated, especially certain oaks, are not, and they increase the hazard to the former. Although large representation of the highly favored food species increases the danger of defoliation, any factors such as fire, grazing, and overcutting that contribute to general stand deterioration increase the susceptibility of the stand to damage (Bess, Spurr, and Littlefield 1947). The condition of the forest floor is particularly important in controlling the population of gypsy moth: a well-developed litter increases the population of mammals and insects that feed heavily on gypsy moth larvae. Stands with no oaks, alder, gray birch, basswood, willow, river birch, poplars, box elder, and hawthorn are seldom defoliated; and if paper birch and larch are also absent, the likelihood of heavy defoliation is very small.

Mortality resulting from gypsy moth defoliation is dependent on extent of defoliation and other factors such as drought or other insects that may weaken the trees. During a 10-year period (1912–1921) mortality of highly favored food trees, with an average defoliation of 37 per cent, was 30 per cent (Baker 1941). Between 1912 and 1915, when trees were weakened by other factors, 62 per cent of the trees died.

In southwest Maine, 80 per cent of the forest is classified as either fully or dominantly resistant to gypsy moth damage (Behre and Reineke 1943). Thirty-three forest types have been classified according to gypsy moth resistance, and a silvicultural priority has been given for each.

The hardwoods are susceptible to *rot* when the wood is exposed. Sprouts from large stumps are therefore frequently defective. It is a

coincidence that three of the favored food species of the gypsy moth, aspen, gray birch, and basswood, are highly susceptible to rot at an early age. Red maple and beech are also highly subject to decay.

ECONOMIC BASIS

Special expenditures for disease and insect control are generally unnecessary, because measures designed to provide for stand improvement are effective in alleviating the disease and insect menaces. For a full discussion of the financial aspect of these practices see p. 68.

CONTROL

To control the gypsy moth effectively, all-round good forest management is essential. Prevention of land abuse, grazing, and fire will aid materially in building up a biological condition in the forest floor and the forest itself which will make stands more resistant to the gypsy moth. Control of the composition of stands through cutting so that the highly favored food species of the gypsy moth will constitute considerably less than 50 per cent of the stand must be accomplished as an accompanying measure. The treatment of stands according to silvicultural priority should help to secure the most effective results from stand improvement work.

Where cultural measures are not entirely practical as a control for the gypsy moth, spraying with DDT at a cost of $1.50 per acre appears to have promise (Sheals 1947). Application by airplane of a 6 to 12 per cent solution of technical grade DDT at a rate of 1 gallon per acre seems to be another means of controlling the gypsy moth (Sheals 1947).

Control of Animal and Logging Damage

Because of the high susceptibility of the hardwoods to injury by grazing animals, domestic livestock should be excluded at all times. A limited area in Massachusetts showed considerable porcupine damage to hemlock, sugar maple, and basswood, and there were indications that, where porcupines were numerous, some adjustment might have to be made in silvicultural practice (Curtis 1941).

Prevention of damage by logging to trees above reproduction size should be stressed, because these larger trees are not quickly replaceable. The breakage or cutting of seedlings need not be discouraged because the subsequent sprouts are generally superior to the original seedlings.

GRAY BIRCH–RED MAPLE TYPE

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of Forest

Importance.
  Area—Major.
  Commercial Value—Minor.
Sites Occupied—Abandoned farm lands and cut-over lands on all kinds of soil, but particularly the sandier soils.
Associated Species.
  Major—Gray birch, red maple.
  Minor—Quaking aspen, pin cherry, yellow birch, sweet birch, paper birch, eastern white pine, sugar maple, red oak, white oak.
Place in Succession—A short-lived temporary type succeeded most often by the white pine type. On the heavier soils, hardwoods may follow.

Gray birch–red maple stands are chiefly even-aged but are two-storied, with the white pine and more valuable hardwoods in the understory. The white pine in the older stands has poor form owing to suppression.

The stands contain chiefly trees of sapling or pole size, few stands being over 50 years old. The stands are irregular in stocking, with overstocking characteristic of a considerable area.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction varies greatly from one stand to another. The older dense stands often support little or no advance reproduction. Eastern white pine, present as reproduction in many stands, is often present as sapling-sized trees in those stands in which the pine became established at the same time or soon after the establishment of the gray birch and red maple. Stands under 25 years old, even the densest, contain some white pine (Toumey 1919). Sugar maple, northern red oak, white ash, and yellow birch occur in variable quantity in most stands. Other hardwoods are seldom present.

Subsequent Reproduction. To increase the amount of natural reproduction of the more valuable hardwoods and white pine by cutting is generally impractical owing to the deficiency of trees of seed-bearing size and the fact that cutting, by creating a more open site, favors regeneration of the low-value species, namely, gray birch and quaking aspen. Since any kind of cutting results in the establishment of some

reproduction—seedling, sprout, and sucker—of these sepcies, the stand after cutting will have a complex composition if advance reproduction was present. In the absence of advance reproduction, the stand will be composed largely of low-value species.

Effect of Competition. Because the low-value species grow rapidly, generally not more than 5 years will elapse before they are as tall as, or taller than, the advance reproduction. Soon after this height is reached, the advance reproduction is adversely affected by the competition from the subsequent reproduction; gradually growth decreases and vitality becomes lower. The more tolerant hardwoods of the advance reproduction, like sugar maple, persist in spite of the competition, but mortality among the other hardwoods and white pine gradually increases. Within 25 years practically all white pine will have disappeared from the stand. The ultimate result of unrestricted competition is a stand of inferior hardwoods similar to the original one.

Windfall. Windfall is a minor factor in the life history of the gray birch–red maple type, because the trees that compose it are well rooted. Windbreakage is a more important factor, especially in the mature stands where butt rot has weakened many of the trees so seriously that they are easily broken by high winds. Severe windbreakage may act as a release cutting.

Economic Basis

The major species of merchantable size in the gray birch–red maple type, namely, gray birch and quaking aspen, can be classified definitely as low-value trees. Rarely can they be utilized for any product other than fuelwood, which seldom yields much profit. Furthermore, butt rot develops when the trees are still relatively small, coincident with distinctly decreased growth at 30 years of age, so that it is practically impossible to produce products of higher value by increasing the length of the rotation.

The financial aspects of handling gray birch–red maple stands to produce tree crops of value are much the same as that of the white pine types (see p. 50).

Application of Methods

Silvicultural treatment is predicated on the fact that profitable utilization of the land is dependent on the development of a crop of species of higher value than those in the original stand. This implies the replacement of the gray birch–red maple type by some other forest

type, preferably conifers, because the soils are generally too infertile to produce valuable hardwoods.

Conversion by Clearcutting or Partial Cutting. In stands where vigorous reproduction is adequate, clearcutting should be applied (Dana 1930). If the reproduction is weakened, the stand should be removed in two cuttings so that ice and snow will not damage it. Partial cutting also prevents undue damage to white pine reproduction by the white pine weevil. Although there may be some financial advantage in postponing the cutting until the trees are large enough for fuelwood (Spaeth 1922), there is grave danger in postponing the cutting if aspen and gray birch dominate the stand, because it will invite trouble from the gypsy moth. Therefore, the cutting should be made before a moth colony becomes established (Behre, Cline, and Baker 1936). The cutting of the original stand must be followed by cleanings that aim to reduce the favored food species of the gypsy moth to a minimum and to free the white pine and valuable hardwoods. These cleanings should follow the same general plan as in the white pine types.

Conversion by Planting. In stands where advance reproduction is deficient conversion can be accomplished to advantage only by planting. Eastern white pine appears to be the best species for this purpose, although red pine may be used if the danger from infestation by the European pine shoot moth or sawflies is low. In open stands or on sandy soils planting can precede the removal of the overhead canopy, but in dense stands or on the better soils planting should follow the removal of the overhead canopy. When the planting precedes the removal of the overwood, the latter operation should be done in 3 to 8 years after the planting. Cleanings must generally follow unless the planted pine attains a height of 4 feet, in which case cleaning may be unnecessary. When planting follows the removal of the original stand, cleanings are always necessary.

Slash Disposal

The relatively small volume of slash and its rapid decomposition (gray birch and aspen slash are in an advanced stage of decay in 2 to 3 years) make the slash hazard of gray birch–red maple cut-over lands low to moderate. Slash is seldom, if ever, so dense over a large area as to interfere seriously with the development of reproduction. The slash can, therefore, be left on the ground as it falls.

Disease and Insect Problems

The gray birch–red maple type is very susceptible to damage by the gypsy moth because of the predominance of the favored food species of the moth (see p. 70). Under the circumstances the white pine is subject to complete defoliation, which is usually fatal. The white pine when completely freed from an overhead hardwood canopy is highly susceptible to attack by the white pine weevil. The effects of the gypsy moth attack, however, may be more serious than those of the weevil (Behre, Cline, and Baker 1936).

Butt rot is common in quaking aspen and gray birch by the thirtieth year. As much as 50 per cent of the wood volume is often worthless by the fiftieth year. Decay is noticeably less in red maple, although serious, and decidedly less in other species.

Control of insects and disease are dependent on properly timed cutting of the stand and conversion into a type composed of less susceptible species. The details of these measures are outlined under "Application of Methods," pp. 73 and 74.

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3 · *Oak Region*

DESCRIPTION AND HISTORY

Location and Landownership

The oak region as described here includes the two regions referred to by Dana (1930) as the oak and the pine-oak regions, a portion of which has been known as the sprout-hardwoods region (Hawley and Hawes 1912). Recognition of the pine-oak region as a part of the oak region is considered advantageous in view of its small area and the relatively low commercial value of parts of it.

The oak region includes a large area in which the oaks are the most important species, although locally, especially in southern New Jersey and on Long Island, certain pines predominate. The region embraces practically all of Connecticut, a small corner of southwestern Massachusetts, southeastern and central New York, Rhode Island, the extreme southwestern part of Massachusetts, all of New Jersey, and most of Pennsylvania except a strip covering the northern one-fourth of the state and the Alleghenies (Fig. 1). The total forest area is approximately 16,000,000 acres. Farm woodlands are of considerable importance in some parts of the region, constituting 62 per cent of the forest area in Connecticut, 28 per cent in Pennsylvania, and 33 per cent in New York. There are no national forests. A considerable acreage of forest land, estimated at 2,500,000 acres, is owned by the states, part of which is organized as state forests.

Physiographic Features

Most of the oak region lies at a relatively low elevation, between 200 and 1000 feet, except parts of Pennsylvania, where the altitude reaches more than 1500 feet. Much of the region consists of a series of gently rolling hills. Exceptions to this are found locally in Connecticut and extensively in Pennsylvania. In the latter state there is

a considerable area of high mountain ridges with gentle lower slopes and very rugged upper slopes characterized by talus deposits and rock outcrops. Broad plains adjacent to the larger rivers add variety to the land surface. The flat sandy plains of New Jersey and Long Island are distinct topographic features.

The soils are of glacial origin except in Pennsylvania, where they are chiefly residual. Conspicuous in the region, but relatively limited in extent, are the coarse, sandy soils of New Jersey and Long Island. Elsewhere, sandy loams predominate. Heavy clay soils are found locally, but in the aggregate they do not represent a large area. Mucks and peats are typical of the low and poorly drained lands.

Most of the soils are moderately fertile and are characterized by an abundance of loose rock or by the nearness of the bedrock to the surface. These features and the steepness of the gradient are important factors in the low agricultural value of much of the land. In Pennsylvania and New Jersey and along the seaboard in Massachusetts, Rhode Island, and Connecticut, extensive areas are valuable primarily for the production of timber. It is estimated that between 30 and 40 per cent of the total land area of the region is more suitable for growing forest than agricultural crops.

Streams are numerous; several are large. Most of the rivers drain into the Atlantic Ocean by way of the Delaware and Chesapeake Bays and Long Island Sound. In southwestern Pennsylvania the streams drain into the Ohio River. In the northeastern part of the oak region, the Housatonic, Connecticut, and Thames Rivers are the chief water courses. Farther west the Hudson River and its tributaries drain most of New York, and to the south the Susequehanna and Delaware Rivers flowing into the Chesapeake Bay and the Delaware Bay, respectively, drain most of Pennsylvania and New Jersey.

Lakes and ponds are well distributed through the region, with the exception of central and southern Pennsylvania.

Climatic Features

The climate is characterized by an abundant well-distributed precipitation, a humid atmosphere, a fairly long growing season, and rather mild winters with a moderate amount of snow.

The average annual precipitation varies sectionally from approximately 26 to 50 inches (Weather Bureau 1926), earth configuration and altitude being the controlling local factors. The precipitation is well distributed, the mean monthly precipitation being below 3 inches

in only a few isolated spots. For the major part of the region, June, the driest month, is followed by 2 months of more than average rainfall. Snow, falling mostly between November and April, constitutes a relatively small part of the precipitation. For most of the region mean annual snowfall is 40 to 50 inches, but in parts of New Jersey and Pennsylvania it is as little as 19 inches.

Because of the proximity of most of the oak region to the Atlantic Ocean, the relative humidity is rather high. Except for short periods when it falls to 30 or 40 per cent, the relative humidity ranges from 65 to 85 per cent.

There is a wide range in temperature from the coldest to the warmest season. The mean temperature for January, the coldest month of the year, varies by localities from 25° to 35° F. The coldest January temperature on record is −20° F. The mean temperature for July, the hottest month of the year, varies from 72° to 76° F. Nearly every station in the region has at some time recorded a maximum temperature of 100° F. or more. The mean annual temperature varies by sections from 48° to approximately 55° F.

A period of about 6 months, extending from the middle or latter part of April to well into October, is free of any killing frost (Weather Bureau 1926).

Electrical storms are common during summer, but, since they are nearly always accompanied by an abundant precipitation, they are unimportant as a fire hazard.

The prevailing wind is from the northwest and north. Locally it shifts to the south during summer. Especially along the coast, high winds are fairly common. Wind velocities up to 67 miles per hour are on record (Weather Bureau 1926). The inland sections are less subject to high winds, records showing wind velocities up to 30 and 40 miles per hour. The eastern part of the region experienced a hurricane in 1938.

Development of Lumbering

Although it is not definitely known when lumbering in this region began, it is believed that some cutting was done early in the seventeenth century in the more accessible sections along the seaboard. The inland areas, particularly in Pennsylvania, were not cut until considerably later. As soon as coal and iron mining developed there, cutting progressed at a very rapid pace, chiefly for charcoal stock. For many years, this region has not been able to supply the local demand for timber products. Pennsylvania, for example, in 1922 was supplying

only 58 of its 309 board feet annual per capita consumption of wood (Illick 1923) and, in 1935, about 30 per cent of its timber needs. Second-growth forests supply all the timber.

Small lumbering operations are characteristic of the region. Very few tracts, by themselves, are large enough to support a permanent mill. Portable sawmills produce a large portion of the lumber. The mill operators move from place to place, setting up their mills wherever 50,000 to 75,000 board feet of timber is available.

The Effect of Past Practices

As the region developed industrially, the demand for agricultural land increased. This demand stimulated clearcutting and subsequent development of the land for agriculture. The poorest soils were soon abandoned for agricultural use. Then, as agriculture advanced in the Middle West, somewhat better farm lands were given up. This abandonment occurred increasingly often during the early part of the twentieth century. Trees became re-established on many deserted farms.

The practice of close and frequent cutting on lands that were not cleared has led to serious deterioration in the quality of the forests. Dependence for regeneration in hardwood stands was placed almost entirely upon coppicing. As long as the chestnut was an important component of the forest, this form of regeneration was reasonably satisfactory. However, with its elimination by the chestnut blight, large yields of timber could not be produced so easily on a short rotation. Repeated clearcutting has increased the proportion on inferior species in the stands and the amount of defect in the tree sprouts (Tryon 1930). A survey of four state forests in Connecticut revealed that 19 per cent of the trees had one or more defects, exclusive of form defects (Kienholz and Bidwell 1938).

Until recently little attention was given by most landowners to protection of the forests from fires. Occasional light surface fires injured the tree trunks, killed seedling reproduction, and burned the litter and humus, thereby causing site and stand deterioration (Buttrick 1912, Tryon 1930). Repeated fires often were followed by a replacement of the valuable oak types with a worthless bear oak type.

When the chestnut blight was first discovered in 1904, the potential seriousness of its work was not fully appreciated. Many forest land owners were of the opinion that the blight could be controlled effectively and that they could continue to grow chestnut. It was soon learned, however, that the disease was a virulent one and that the American

chestnut was doomed to extinction. In 1914, 10 years after the chestnut blight was discovered, Toumey (1914) advised the conversion of chestnut stands to other hardwoods, pine, or spruce. Conversion to conifers had the support of numerous landowners, because it appeared that conifers would be more profitable than hardwoods because of their superior growth (Barnes 1917). A small acreage of lands on which chestnut had been strongly represented was planted with a variety of conifers, particularly eastern white pine, Scotch pine, Norway spruce, and red pine. European larch was used with success in some instances (Richards 1917). The planting of conifers on abandoned farm lands and lands formerly occupied by American chestnut has added to the acreage of coniferous forest. The increase of white pine, particularly in the form of pure stands, has led to a marked increase in damage by the white pine weevil (Maughan 1930).

Some improvement in forestry practice has taken place in recent years. More attention is being given to protection of the forests against grazing and fires. In consequence, seedling reproduction of valuable species is increasing, and stocking and quality of timber are improving. Some forest land owners, appreciating the value of cultural operations, are pruning some of their white pine and making cleanings, improvement cuttings, and thinnings in pine as well as hardwood stands.

THE FORESTS AND THEIR MANAGEMENT

The oak region has a diverse forest cover, not less than twenty types being represented in sufficient area to be recognized as distinct forest types. The oak types, of which there are six, the yellow pine types, of which there are three, and the shortleaf pine-oak types, of which there are three, are the most important from the standpoint of area and commercial value. Less valuable, but numerous, are the black ash–American elm–red maple, the bear oak, the hemlock, and the eastern redcedar types. Each of these seven types or type-groups, except the shortleaf pine-oak types, will be discussed in detail. Others less widely distributed in the oak region but of considerable importance locally are the white pine and the white pine–red oak–white ash types (see New England white pine region, pp. 44, 45), the red pine type (see Lake states region, pp. 318–324), the Atlantic white-cedar types (see southern pine region, pp. 237–241), and the sugar maple–beech–yellow birch type (see Allegheny hardwood–pine–hemlock region, pp. 125–135). The white pine and red pine types are increasing in area each year through the extensive planting of these species.

OAK TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. Five distinct oak types and a sixth so similar silviculturally that it is included here constitute the oak type-group. The individual types are outlined in Table 4.

The oak forests are second growth with sprouts usually making up 50 to 75 per cent of the stems in young stands (Leffleman and Hawley 1925, McIntyre 1933). Cutting, fire, and grazing of the past are responsible for the generally depreciated stand composition, understocking, and large amount of defect in most of the oak forests. Young stands predominate, but a few stands of limited acreage are as old as 80 to 90 years.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction in unmanaged stands is often sparse or entirely absent, fire or grazing by domestic livestock or deer generally making establishment impossible (Averell 1929). Where these factors are not limiting, high stand density may prevent satisfactory establishment of reproduction. Systematic thinning or stand improvement leads to an abundance of advance reproduction in the older stands (Leffleman and Hawley 1925) (Fig. 16). Openings in stands caused by the death of the chestnut are commonly well stocked.

Subsequent Reproduction. In the absence of adequate advance reproduction the future stand is likely to be understocked unless ample provision is made for the establishment of subsequent seedling reproduction. If the stand is not too old, a partial stand of reproduction develops from the sprouting of the stumps after any type of cutting. Red maple is the most prolific sprouter, followed in order by chestnut oak, sugar maple, beech, northern red oak, white ash, white oak, scarlet oak, black oak, hickories, and sweet birch (Averell 1929). In a limited study in New Jersey, scarlet and white oak produced more multiple-stemmed sprout clumps than post, black, and chestnut oak (Wood 1939*a*).

Averell (1929) emphasizes the importance of an abundant seed supply and a protected site in the establishment of abundant subsequent seedling reproduction. Seedling oak reproduction presents the most critical problem. Acorn production is adequate, but animals and insects damage or destroy so much of the seed crop (87 per cent in a

TABLE 4

DESCRIPTION OF THE OAK TYPES

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Chestnut oak	Moderate	Moderate to low	Dry ridges and slopes, particularly where soil is thin and rock outcrops common	Chestnut oak, sometimes pure	Scarlet oak Pitch pine Virginia pine Shortleaf pine Post oak Red maple	Climax type
Scarlet oak–black oak	Secondary	Moderate to low	Dry ridges and slopes	Scarlet oak Black oak Various hickories	Pitch pine Chestnut oak White oak	Climax type
White oak–black oak–northern red oak	Secondary, except in Pennsylvania	Moderate	Well-drained loams	White oak Black oak Red oak	Various hickories Yellow-poplar White ash Red maple Black tupelo	Semi-permanent type, gradually giving way to type containing more sugar maple and some hemlock
White oak	Major	High	Well-drained loams	White oak, pure or predominant	Black oak Yellow-poplar Shagbark hickory Mockernut hickory	Ditto
Northern red oak	Major	High	Well-drained loams, particularly north slopes	Red oak, pure or predominant	Black oak Scarlet oak Chestnut oak Yellow-poplar	Climax type
Northern red oak–basswood–white ash	Moderate	High	Deep, fertile, moist, well-drained soils	Red oak American basswood White ash	Sugar maple Yellow birch Sweet birch Eastern white pine	Semi-permanent type, gradually giving way to type containing more sugar maple and some hemlock

New Jersey study) that little seed is left to germinate (Wood 1938). Wood's New Jersey study also calls attention to the importance of site protection in satisfactory germination of acorns. It also found that young seedlings were often injured or destroyed by animals, leaf-, stem-, or root-eating insects, and diseases.

Photograph by Yale School of Forestry.

FIG. 16. A second-growth oak stand that has reached maturity. Abundant reproduction has become established as a result of improvement cuttings.

For the oaks, seed trees must be reasonably close together and uniformly distributed, because the seed is disseminated only a short distance. Pine seed trees need not be so numerous to insure an adequate seed supply, because dissemination is more widespread. It is not difficult to provide for an ample seed supply of hemlock, yellow-poplar, or white ash, because these species are fairly good seed producers and their seed is readily disseminated to a considerable distance.

A moderately well-protected site seems to be best for satisfactory germination of most of the more valuable species. Hemlock fares best with a maximum of protection (as in the hemlock type, see p. 109). The pines, yellow-poplar, and white ash prefer a moderately open site.

In contrast, the less valuable species succeed best on an exposed site.

Animals (see p. 100) and drought may interfere with regeneration by killing young seedlings or by altering the composition of regeneration through greater damage to some species than to others.

In spite of the factors that tend to limit reproduction, adequate regeneration of a desirable character becomes established when systematic management is applied, as evidenced by a detailed study of one area in Connecticut (Leffleman and Hawley 1925). On the better sites the composition of the reproduction is generally complex; on the poorest sites the oaks, particularly the chestnut oak, are dominant.

Competition between Species and Growth Forms. The growth and development of the reproduction depend upon several factors, particularly the origin of the reproduction, its composition, and the source and intensity of the competition. The growth of subsequent reproduction of sprout origin is approximately one and one-half to two times as fast as that of advance reproduction of the same origin, whereas there is little difference in the rate of growth of advance and subsequent reproduction of seedling origin, the slight advantage being with the advance reproduction (Leffleman and Hawley 1925). Greater differences in rate of growth following full release by cutting exist between the different growth forms, subsequent sprouts growing two to three times as fast as subsequent seedlings, whereas advance sprouts grow only slightly faster than advance seedlings. Single and multiple subsequent seedling sprouts are intermediate between seedlings and sprouts in rate of growth. Obviously, when sprout forms of subsequent reproduction outnumber other forms, they are likely to maintain their superiority in competition. In later life differences in rate of growth of the various growth forms becomes less pronounced.

Red maple, because of its rapid growth, is the most serious competitor of other species in the northern part of the region. In the southern part, where chestnut sprouts are often abundant, the chestnut is the chief competitor of other species, and will continue to be so as long as the chestnut continues to sprout (Aughenbaugh 1930). In general, the chestnut and the red oaks withstand competition best of the other species because of their more vigorous growth. In New Jersey, white oak showed poor form because of the high persistence of stems in clumps and slow growth (Wood 1939*a*). In contrast, scarlet oak with large numbers of stems per sprout clump overcomes this disadvantage through its rapid growth. First-year mortality of scarlet and black oak sprouts is greater than that of other species (Little 1938).

Shrubs, although often abundant in the stand, are not a serious menace to the tree reproduction because their growth is slower than that of the slowest-growing tree species. In spite of the advantage that the less desirable forms and species of tree reproduction have, untreated stands will ultimately contain a good representation of well-formed seedlings, and seedling sprouts of oaks and the more valuable hardwoods, with, however, some loss in growth and quality because of the uncontrolled competition (Leffleman and Hawley 1925).

Windfall. The hardwoods are rarely uprooted because they are deeply rooted, except on some of the ridge tops, where a shallow soil does not permit normal root development. Of the conifers pitch pine is the most susceptible to windthrow, particularly in late life when the root system seems to be especially weak.

Windbreakage is generally associated with defect in the bole, particularly cankers and decay.

Economic Basis

Utilization and Marketing Problems. In spite of the fact that the demand for forest products greatly exceeds the local supply, opportunities for the most profitable utilization of the oak types are woefully inadequate (Hawes 1929, Illick 1923, Ludwig 1923). Contraction of the demand for fuelwood in recent years, together with the high transportation charges in getting it to market from the less accessible areas, both of which militate against profits in handling the product, have materially decreased the possibility of utilizing the smaller materials advantageously (Hawes 1929, Ziegler 1926).

It is hoped that the use of improved wood-stove and furnace units may recapture some of the fuel market and thus broaden the outlet for products from small trees. Mine props and timbers provide an outlet for small trees only in the mining districts where the demand is very active. The deficiency of satisfactory large wood-utilization plants, brought about undoubtedly by the general scarcity of high-quality timber in recent years, often makes impossible the best use of the better-quality trees, thus rendering their most profitable use impossible. The strong demand for railroad ties in most of the region provides a reasonably good outlet for timber of intermediate quality. A study of a small area showed that logging and milling costs for producing cross ties increase rapidly on trees under 14 inches d.b.h. and that costs on trees between 14 and 20 inches show little variation (Cunningham and Ferguson 1946). Above 20 inches, costs decline somewhat.

Although there is some local variation in the relative commercial value of the various species occurring in the oak forest, it is probable that their segregation into three groups by Korstian and Stickel (1927) is applicable in general. This arrangement, in which group 1 represents the most valuable species, group 2, those of intermediate value, and group 3, those of lowest value, is shown in Table 5.

TABLE 5

SPECIES OF THE OAK TYPES GROUPED ACCORDING TO THEIR COMMERCIAL VALUE

Group 1	Group 2	Group 3
Northern red oak	Scarlet oak	Flowering dogwood
White oak	Red maple	Gray birch
Black oak	American beech	Bear oak
Chestnut oak	Black tupelo	Sassafras
Hickories	Quaking aspen	American hornbeam
White ash	Bigtooth aspen	Eastern hophornbeam
Sugar maple	Eastern cottonwood	Witch hazel
Sweet birch		Downy serviceberry
Black cherry		
Yellow-poplar		
American basswood		
Eastern white pine		
Pitch pine		

Obviously the relative value of the group 1 species varies because of growth differences and local demand for various products. For example, where handle stock is in demand, white ash is a particularly valuable tree because of both this demand and its rapid rate of growth. Hemlock, a species not included above, is classed as a group 1 species.

Specific data on the most profitable tree sizes for saw-log production are not available, but it is generally believed that trees under 15 to 17 inches d.b.h. are not profitably converted into saw logs.

Growth and Rotation. The yield capacity of the oak types has been reduced materially by the elimination of the American chestnut, since the temporary increase in growth of individual trees of 26 to 53 per cent does not make up for the loss of 23 to 48 per cent in growth for the stand as a whole (Korstian and Stickel 1927). Trees of sprout origin grow faster than those of seedling origin for the first 25 to 40 years, but at 55 to 75 years there is little difference in the diameter attained by the two (Frothingham 1912, Spaeth 1928). Periodic cut-

tings are essential to the maintenance of rapid growth, Spaeth (1928) finding in New York that the time required to produce a 9-inch white oak and chestnut oak could be shortened 20 and 24 years, respectively, by improvement cuttings.

Red oak exceeds all other species in rate of growth according to Spaeth (1928) and Lutz (1928), after which come, in order, black oak, chestnut oak, and scarlet oak. On the better sites American basswood and yellow-poplar grow rapidly.

Saw logs can be grown in approximately 75 years on the better sites. The poorest sites yield little saw timber on a rotation of 100 years (McIntyre 1933).

Financial Aspects. Specific data on the financial aspects of the silviculture of oak stands are meager. It is generally agreed that oak stands cannot be expected to be profitable unless cultural measures are applied. Whether cleanings or improvement cuttings are the most advantageous depends on local circumstances. If there is a near-by local market for fuelwood or pulpwood, in which case these products can be marketed at a profit from stands over 20 years old, improvement cuttings or thinnings are likely to prove more profitable in the long run than cleanings, which represent a cash outlay of $1.50 to $7.00 per acre. An oak stand in New Jersey was thinned at a profit of $35.00 per acre (Baker 1925). If low-value species are especially abundant, postponement of cutting may not be practicable.

The economic soundness of converting certain oak stands, particularly those on poor sites and those with a strong representation of chestnut, into coniferous stands is open to question.

Application of Methods

Although various methods of treatment have been suggested for managing mature oak stands, each aiming at the production of a specific type of crop, it seems that, for the bulk of the area, the objective of the treatment should be the maintenance of the oak type, which implies the encouragement of a maximum amount of the more valuable hardwood species (Dana 1930, Korstian and Stickel 1927, Leffleman and Hawley 1925, Spaeth 1928). The possibilities of attaining other goals will be outlined in later paragraphs.

Shelterwood Cutting. In even-aged mature stands having inadequate reproduction, shelterwood cutting provides the best means of controlling the composition and encouraging the establishment of seedling reproduction (Dana 1930, Durland 1922, Spaeth 1928).

Dana's suggestion of substituting clearcutting, followed by planting of the understocked areas for shelterwood cutting in stands supporting a moderate amount of reproduction, has merit when economic conditions do not justify removal of the crop in two cuttings.

The first cutting of the shelterwood method should remove approximately one-half of the merchantable volume. The less valuable species and defective trees should constitute the bulk of the trees removed. If saw timber is to be the chief product, group 1 species should be retained for seed. Hemlock can be retained to advantage also. Ordinarily reproduction is sufficiently well established in 4 to 8 years after the first cutting to make the second cutting then feasible. This cutting should include all remaining merchantable trees.

Selection Cutting. The selection method of cutting is recommended for uneven-aged mature stands (Hawley and Maughan 1930). Cutting will be most effective in accomplishing the desired results if applied as a group-selection method. This form of cutting will encourage the regeneration of hemlock and the better hardwoods. The choice of species should be the same as for the shelterwood method.

Favoring Conifers. Since conifers, hemlock, eastern white pine, and the hard pines, on the respective sites on which they occur, are valuable components in oak stands, they should be favored to a certain extent. Since hemlock is a potentially valuable tree in oak stands because it can increase the yield and aid in improving the quality of the hardwoods, the encouragement of a moderate amount of hemlock in oak stands is recommended (Lutz 1928, Merrill and Hawley 1924) (Fig. 17). To accomplish this objective, partial cutting is essential, by the shelterwood method in even-aged stands, and by the selection method in uneven-aged stands (Merrill and Hawley 1924). Cuttings as light as economic conditions will permit should be encouraged. This is particularly true where sweet birch is abundant. In such stands openings in the canopy should not exceed 35 feet and should average only 20 to 30 feet.

The possibility of alternating hemlock with oak crops, as suggested by Merrill and Hawley (1924), should be carefully studied for stands in which hemlock is strongly represented before cutting. If the understory hemlock (the usual form in which hemlock occurs when abundant) is favored in thinnings and improvement cuttings, the final removal of hardwoods leaves a stand composed largely of sapling and pole-sized hemlock for the second crop. As the hemlock stand reaches maturity the natural conditions in the stand favor hardwood repro-

Photograph by Yale School of Forestry.

FIG. 17. Hemlock is silviculturally desirable in oak stands. It aids in pruning the hardwoods and it adds to the yield of the stand.

duction, with the result that the third crop will consist chiefly of hardwoods.

Clearcutting. Clearcutting can be recommended only for the immediate future for stands with an abundance of advance reproduction and a preponderance of saw-log trees of profitable size (Dana 1930). Openings in the reproduction stand should probably be planted. As marketing conditions improve, more intensive methods of treatment should be developed.

Conversion to Pine. Although conversion of the oak types on the poorer sites to eastern white, red, or pitch pine has been suggested (Durland 1922), there is insufficient evidence to justify either a recommendation or condemnation of the procedure. The high cost of the large planting stock that would usually have to be used and the high cost of cultural operations to maintain the pine, because the ecological trend is away from pine, are major objections that can be raised.

Cultural Operations. Whether the improvement of the stand composition should be accomplished by cleanings or improvement cuttings must be determined by economic considerations (see p. 90). Where the matter is definitely debatable the odds are probably in favor of cleanings, since the rotation can be shortened and the final crop can be greatly improved thereby (Fig. 18).

Cleaning. In applying cleanings three classes of trees should be removed: (1) flat-topped trees so deformed as to have no future value, (2) dominant stems of low-value species that are overtopping desirable species, (3) dominant trees of sprout origin (Leffleman and Hawley 1925). Species selection should be based on the group classification previously referred to (p. 89).

The first cleaning should be applied 5 years after the final removal cutting. One cleaning frequently suffices, but more often a second cleaning, 4 or 5 years after the first, is necessary. This is particularly true where red maple is abundant. Tryon and Finn (1942*b*) found that three cleanings are sometimes necessary. However, they (1942*a*) found encouraging evidence that poisoning with a calcium chlorate or an ammonium thiocyanate solution, which was 100 per cent effective in preventing sprouting in one test, might be substituted, at a great saving in cost, for cleanings.

Improvement Cutting. When improvement cuttings are substituted for cleanings, the first cutting should, of course, be applied when the trees are large enough to be salable. These cuttings should be 5 to 12 years apart, depending on marketing conditions. The first cutting

should concentrate on the removal of dominant trees and low-value species.

The objective of all improvement cuttings should be a maximum yield of saw-log trees. This implies that crooked, forked, and other-

Photograph by Yale School of Forestry.

Fig. 18. A young sapling oak stand of seedlings and seedling-sprouts. Cleanings or improvement cuttings are necessary in such stands.

wise defective trees, particularly sprouts, should be removed gradually. Since these low-value trees are generally abundant, a word of caution must be given to guard against too heavy cutting. In the early cuttings many low-value trees must be retained as trainers.

Special care must be exercised in stands in which chestnut was originally abundant to avoid overcutting. If natural regeneration in the openings is slow, planting may be advisable.

Pruning. Although pruning cannot be recommended as a general practice, the author advises it for the better stands on productive sites as an aid in controlling the strumella disease and nectria canker and to improve timber quality (Moss 1937). Limiting the pruning to selected trees with limbs under 2 inches in diameter appears advisable until more data are available.

Planting. Forest planting in the oak types is a major consideration only on lands originally occupied by oak forest, subsequently used for farming, and then abandoned. On the timbered land itself, planting should be used only to reinforce stands deficient in natural reproduction (where it is impractical to secure natural reproduction) or to convert oak to coniferous stands (a practice of questionable merit).

Adaptability to the site must be given careful consideration in the selection of species to be planted. Hardwoods should be given first choice for the better sites that have not deteriorated seriously from erosion and sites that receive some protection from adjacent stands or topographic features. Recently cultivated old fields and areas with large rodent population are not good sites for hardwoods (Special Committee 1943). Red oak, black locust, sugar maple, red ash, and chestnut oak have proved their worth in Connecticut and should grow equally well in other parts of the region (Hicock 1924). Recent evidence indicates that group mixtures of hardwoods and conifers are preferable to plantings of hardwoods alone (Special Committee 1943). Well-drained sites may be prepared by furrowing if this will not put the tree roots in an impervious clay subsoil. If slit planting is used on heavy soils, soil compression should be kept at a minimum.

For areas naturally poor, or made poor by improper agricultural practice, conifers should be chosen. Eastern white pine, if planted with discretion, that is, with close spacing and with other species in mixture (these practices decrease the insect hazard and improve the quality of the white pine), can be planted to advantage here (Hawley 1924). Red pine, European and Japanese larch, and shortleaf pine are recommended for moderately fertile ground. Pitch pine is best for the poorer sites because of its rapid growth (Stevenson and Bartoo 1940) and resistance to the gypsy moth (Hall 1935). Norway spruce is effective in mixtures. Japanese black and Japanese red pine, once recommended (Ludwig 1923), have more recently been a failure, and therefore they should not be used.

Red pine and white pine, as well as red pine and Norway spruce, in small alternate blocks have proved to be satisfactory mixtures in Pennsylvania (Stevenson and Bartoo 1940). In general, mixtures seem to be preferable to pure stands. Red pine is not favored in Connecticut because of damage by the European pine shoot moth (Hawley and Lutz 1943).

Although seedlings were formerly recommended for sites supporting vegetation (Ludwig 1924), recent recommendations favor transplants (Stevenson and Bartoo 1940). Seedling stock must be well-developed 2-year stock, except for white pine, which requires 3-year stock. For conversion of oak to a coniferous type and for areas with a heavy vegetative cover, conifer transplant stock 3 or 4 years old should be used. One-year seedlings are satisfactory for hardwoods.

A spacing of 6 by 6 feet is generally applicable except for red pine (see p. 116). Spacing of 8 by 8 feet seems best for red pine, although wider spacing is feasible if pruning can be applied and if early thinnings are not feasible (Stevenson and Bartoo 1939). Fall planting has proved best for hardwoods (Illick 1920). Several of the conifers have been planted successfully in the fall also, but for general large-scale planting spring is the best season.

Slash Disposal

The volume of slash on cut-over land varies from a light covering where fuelwood is removed to a moderately heavy covering where utilization is less complete. The leaves drop from the hardwood slash during the first few months, and the smaller limbs are fairly well decomposed in 3 to 4 years. Decomposition is complete in 7 to 8 years. Decomposition of hemlock and pine slash is slower. The relatively rapid decomposition of the bulk of the slash and the moderately moist condition of oak sites except during drought years make the slash hazard low, especially after 3 or 4 years.

Slash apparently has neither a beneficial nor a detrimental effect on the establishment of reproduction (Averell 1929).

The foregoing facts indicate that slash can be left as it falls.

Disease and Insect Problems

Ecological Basis

Various cankers, trunk rot, chestnut blight, and the gypsy moth are the most troublesome pests of the oak type.

Three distinct canker-producing diseases, referred to as strumella disease, nectria canker, and *Polyporus hispidus*, have been identified in the oak type. Their action is similar. They enter the tree through dead branch stubs, and that they attack thrifty trees as quickly as unthrifty ones is evidenced by their occurrence on trees of all crown classes. The nectria canker attacks all hardwood species, whereas the other two occur only on the oaks. Black oak is more susceptible to the strumella disease and *Polyporus hispidus* than any other species (Bidwell and Bramble 1934, Sleeth and Bidwell 1937). Infection begins at an early age on the lower part of the trunk, strumella cankers seldom occurring more than 8 feet above ground and *Polyporus hispidus* occurring mostly less than 20 feet above ground.

The cankers attack the cambium, sometimes causing complete girdling of the stem. A slow rotting of the wood is generally associated with the cankers (Fig. 19). The damage is serious because the most valuable part of the tree is attacked. Average losses of wood amount to only 2 or 3 per cent, but over limited areas may run as high as 33 per cent (Sleeth and Bidwell 1937). The strumella disease spreads largely from the heavy fruiting on dead trees.

The *chestnut blight*, discovered in the oak region in 1904, has killed all the American chestnut; but, in the southern part of the region, where the initial infection occurred later than in the north, sprouting from the old stumps continues profusely. It has been reported that many stems have developed an increased resistance to the blight (Aughenbaugh 1930), but the author can discover no biological principle to support this view. For the immediate future the American chestnut cannot be counted upon as a permanent component of the oak stand.

Trees of sprout origin are very susceptible to *butt rot*. A study of decay in unburned sprout oak stands in this region and adjacent regions revealed that several factors influence the incidence of butt rot (Roth and Sleeth 1939). The parent stump was the source of entrance of decay fungi in 86 per cent of the cases. Sprouts from large stumps are more subject to butt rot than sprouts from small stumps. Sprouts that begin below ground are less likely to be infected than those originating above ground, and the chances of infection increase rapidly with the height of origin above ground up to 4 inches. Time of heartwood formation and subsequent connection with the parent stump determine the time that the earliest infection from the parent stump can occur, which is usually at least 10 years. Susceptibility to decay varies with species as indicated by the following percentage of sprouts infected:

Photograph by C. B. Bidwell.

Fig. 19. The zoned appearance of the strumella canker is nearly obliterated by the decay of the wood underlying the canker on this dominant 6-inch black oak.

chestnut oak, 11; white oak, 19; red oak, 22; scarlet oak, 28; and black oak, 39. Nineteen species of wood-rotting fungi were isolated in living sprouts by Roth and Sleeth (1939).

The *gypsy moth* attacks many of the species of the oak type but, except for the Cape Cod area, few serious outbreaks have occurred, owing to factors other than food, not now understood (Behre, Cline, and Baker 1936). The same species as in the New England white pine region are the favored food species of this pest in the oak region (see p. 70).

The *golden oak scale*, an insect that does serious damage to chestnut oak, has been reported to be extensive in southern Connecticut (Parr 1937). Attacks are most severe in poor sites on trees of sprout origin. Trees of reproduction and sapling size are damaged worse than larger trees, sometimes being gradually killed by the insect.

Control Methods

Fire protection, judicious selection of species and types of trees that are removed in all cutting operations, and a certain amount of pruning go a long way toward improving and maintaining the health of oak stands. Favoring group 1 species in the reserve stand eliminates some of the favored food species of the gypsy moth, which is about as much as can be accomplished in the oak types (Behre, Cline, and Baker 1936).

There is no practical method of controlling the chestnut blight.

Removal of infected trees at the first sign of infection is essential to the control of the cankers. The wood from these trees should be utilized if possible in order to remove it as a source of subsequent infection (Bidwell and Bramble 1934, Sleeth and Bidwell 1937). If the trees have been infected with the strumella disease, the dead trees should be knocked to the ground, where they are less dangerous. Early pruning where practical should solve much of the trouble with the cankers, since it should prevent much of the infection (Moss 1937, Sleeth and Bidwell 1937).

Control of butt rot must be accomplished by favoring in cultural operations the sprouts least likely to be infected. Since the factors affecting incidence of decay are more readily recognized in stands under 20 years, control should be undertaken in the young stands wherever possible. Treatment of these young stands should aim at the following:

1. Favor seedlings and seedling sprouts as crop trees.

2. Favor sprouts from stumps less than 3 or 4 inches and not over 6 inches in diameter.

3. Favor sprouts originating low on parent stumps and from low-cut stumps.

4. In cutting fused sprouts, cut flush at the crotch, or as nearly flush as possible without injuring the reserved sprout.

Treatment of stands over 20 years old should aim at the following:

1. Favor single sprouts.

2. Discriminate against sprouts coming from stumps whose wounds are not grown over or from enlarged butts.

3. Either cut all sprouts from a clump of large sprouts that are fused or leave the group intact. If left intact, they may serve as trainers but should not be retained as crop trees.

For short-rotation crops, such as cordwood, less attention need be given to controlling the decay hazard than for long-rotation crops. Since frequently cut stands are generally highly defective, such stands should be developed largely for short-rotation crops. Stands that are badly wounded by fire present the same problem.

No practical control for the golden oak scale is known.

Control of Animal and Logging Damage

A definite program for controlling animals affecting the oak type is needed in order to get the results desired in forest production. Domestic livestock cannot be tolerated where the dominance of the hardwoods is to be maintained. Where it is desired to increase the representation of conifers, judicious grazing—enough to release the conifers from suppression—is advantageous.

Especially in Pennsylvania precautions must be taken against damage to reproduction and even to larger trees by deer. Prevention of overpopulation of the forest by deer is the best cure (Clepper 1931). The use of repellents shows promise but is not adequately developed.

There are no special problems in the prevention of logging damage that need attention.

YELLOW PINE TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. Three distinct forest types, the pitch, Virginia, and shortleaf pine types, are grouped for discussion

because of their silvicultural similarity. Until recently only the shortleaf pine type was considered valuable commercially, but the steadily increased demand for pitch and Virginia pine for pulpwood in recent years has changed their status. The three types are described in Table 6.

TABLE 6

DESCRIPTION OF THE YELLOW PINE TYPES

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Pitch pine	Major	Moderate	Ridges, dry flats and slopes; dry sands of coastal plain in New Jersey	On dry soils: Pitch pine, sometimes pure; Red maple; Chestnut oak; Black oak; Scarlet oak. On moist soils: Pitch pine; Sweet birch; White oak; Northern red oak; Sugar maple; American beech	On dry soils: Bear oak; Dwarf chinquapin oak; Black tupelo; Sassafras. On moist soils: Cucumber magnolia; Yellow-poplar; White pine; Hemlock; Downy serviceberry; Flowering dogwood; Eastern hophornbeam	Temporary type, succeeded by hardwoods
Virginia pine	Secondary in Pennsylvania; increasing rapidly by encroachment on abandoned farm lands	Moderate	Old fields on dry sites	Virginia pine, sometimes pure; Shortleaf pine; American chestnut; White oak; Chestnut oak; Red oak; Black oak; Black tupelo	Pitch pine	Temporary type, succeeded by shortleaf pine and hardwoods
Shortleaf pine	Minor	Moderate	Dry uplands and ridges	Shortleaf pine often pure	Chiefly oaks and pitch pine	Usually succeeded by white and red oak

All the yellow pine stands are second growth, generally even-aged, and irregularly stocked. The oak region has pine stands of many

different ages, but the younger stands predominate. New stands are becoming established on abandoned farm lands and burns.

On the so-called pine barrens of New Jersey, where frequent fires have seriously deteriorated the site, extensive areas of immature forest are poorly stocked with a low sprout growth of poorly formed trees (Lutz 1934).

Stand Regeneration and Development. The three types have much in common in the manner in which reproduction becomes established and the stand develops. The major species, pitch, Virginia, and shortleaf pine generally produce seed frequently and abundantly, although, in New Jersey, shortleaf pine produces heavy seed crops infrequently (Wood 1939*b*). Since germination percentage is generally high, pine seedlings originate in large numbers if fire, domestic livestock, and deer do not interfere. Excessive litter may interfere with seed germination, as was the case with shortleaf pine in New Jersey, and, although scalping and other soil treatments increased germination, seedling survival was generally poor (Wood 1939*b*).

For more details on the regeneration of the shortleaf pine type, reference should be made to the southern pine region (p. 219). Information is lacking on the regeneration of the Virginia pine type. The remainder of the discussion will relate to the pitch pine type, but the general principles of reproduction of this type apply in a broad sense to the Virginia and shortleaf pine types.

Advance Reproduction. Advance reproduction in the pitch pine type varies in quantity, distribution, and composition with the individual stand. Fire is the cause of the deficiency of reproduction in many mature stands. Elsewhere a moderately dense stand condition is inimical to the establishment of pitch pine reproduction inasmuch as it fails to become established where the canopy is over 50 per cent (Illick and Aughenbaugh 1930). Hardwoods generally predominate in the advance reproduction, its composition usually being similar to that of the overwood except where the site has deteriorated severely from frequent fires, in which case quaking aspen, red maple, and sassafras dominate the reproduction. Because of the general deficiency of advance reproduction in pitch pine stands, chief dependence must be placed on subsequent reproduction.

Subsequent Reproduction. The seed characteristics of pitch pine, such as frequent and abundant seed production, high germination capacity, and light weight that allows wide dissemination by wind, put this species in a favorable position to reproduce with ease when the site meets its requirements. These site requirements are: an open

area, such as follows clearcutting or seed-tree cutting, and a reasonably exposed soil (skid trails and roads and soils bared by fire are ideal seed beds) (Illick and Aughenbaugh 1930, Little and Moore 1945). Pitch pines under 8 inches d.b.h. sprout after cutting and develop into trees of average size and good form. This form of reproduction may be of some importance where small trees are cut for pulpwood.

Subsequent reproduction of valuable hardwoods depends on seed trees on the cut-over area. Sassafras and red maple seed often migrate into cut-over areas where they may reproduce abundantly. Downy serviceberry, dogwood, rhododendron, eastern hophornbeam, and mountain laurel, if present in sizes that produce seed, usually reproduce freely on cut-over land. Since all the hardwood species sprout, the amount of sprout hardwoods in the reproduction depends on the abundance of hardwood stems that are cut.

Stand Development. The extent to which pitch pine establishes and maintains itself in a new stand depends to a considerable degree on the amount of competition it encounters from hardwood reproduction (unless deer, which show a decided preference for pitch pine in their browsing, do such severe damage to the pine as to interfere with its growth) (Frontz 1930, Illick and Aughenbaugh 1930). The amount and size of the hardwood reproduction and the quality of the soil determine the extent to which the intolerant pitch pine can maintain itself under natural competition. On the better soils, established hardwoods have a growth advantage over the rapid-growing pitch pine, a serious handicap to the latter. With a sparse stand of hardwood reproduction the pitch pine cannot fail to occupy an important place in the ultimate stand. The general tendency in the composition of the hardwood element is toward a temporary increase in red maple and sassafras but with the longer-lived oaks and other better hardwoods eventually maintaining their representation. Controlled burning in stands in which the pines are at least 2 inches d.b.h. is effective in reducing the hardwood competition without serious injury to the pines (Little and Moore 1945).

Experiments in New Jersey with interplanting as a means of improving the stocking of understocked stands on dry sandy soils have demonstrated that even on the poor soils pines (several species) have difficulty in competing successfully with established hardwoods unless cultural operations are applied, giving additional evidence of the seriousness of the hardwood competition (Wood 1936).

Shortleaf pine is more tolerant than pitch pine, and therefore it is able to compete more successfully with its associates.

Windfall. Pitch and Virginia pine have shallow root systems at maturity, and they are therefore highly susceptible to windfall, especially if the stand is severely opened by heavy cutting (Illick and Augenbaugh 1930, McIntyre 1933). Shortleaf pine, on the other hand, maintains its tap root through life and is seldom windthrown. The hardwoods have well-developed root systems; consequently, they are seldom windthrown. A limited amount of windbreakage is associated with severe rot in the bole of some of the hardwoods.

Economic Basis

Most of the facts relating to the relative value of species and the utilization of timber that were given for the oak types (p. 88) apply in a general way to the yellow pine types. Although the pitch and Virginia pines have little value for lumber, their extensive use in Pennsylvania and their utility in paper manufacture make their woods moderately valuable, at least in that state. Shortleaf pine is also suitable for paper manufacture, but its use is not limited to that industry inasmuch as it yields satisfactory lumber.

The pitch and Virginia pines are the fastest-growing conifers in the region (Morey 1932). Their growth culminates at an early age—Virginia pine at 30 years, and pitch pine at 50 years. Deterioration develops in pitch pine stands as they mature, a factor that definitely limits the rotation age.

Shortleaf pine grows somewhat more slowly than the pitch and Virginia pine, but its growth is sustained over a longer period. A rotation of 80 years yields high-quality lumber.

Thinnings or improvement cuttings can generally be made at a profit in pine stands where there is a near-by market for pulpwood.

Application of Methods

Shelterwood Cutting. To the majority of mature stands—characterized by a deficiency of advance reproduction—shelterwood cutting can best be applied. Moderately heavy cutting that removes 50 to 70 per cent of the merchantable volume of the stand is essential to create the open site demanded by the pines (Dana 1930). Hardwoods should be cut to a low diameter in the first cutting unless the site is sufficiently fertile to produce hardwoods of good quality. The removal

cutting can be made in about 5 years after the reproduction cutting. It is important not to delay this cutting unduly because of the unfavorable effect of the reserve stand on the pine reproduction—particularly if it is pitch or Virginia pine.

Seed-Tree Cutting. Where advance reproduction is fairly abundant, seed-tree cutting, leaving five to ten seed trees per acre, is advisable. Although seed trees might be dispensed with, it seems advisable to retain them until such time as there is assurance of better fire protection than exists now.

Cultural Operations. The need for cleanings (or prescribed burning) depends on the abundance and rate of growth of the hardwood elements of the stand. If hardwoods are sparse or consist of species of slow-growth characteristics, cleanings (or burning) are unnecessary. Although cleanings have been regarded as the only means of improving the composition of young stands of this type, a recent study indicates that better results may be attained by using controlled fire as the chief means of stand improvement and cleanings as a supplementary operation (Little and Moore 1945). The investigators suggest cleanings about every 3 years as a supplement to fire.

Low thinnings, the first when the stand is about 20 years old, should be applied to well-stocked stands.

Prescribed Burning. Although not used widely, prescribed burning appears to have merit as a means of increasing the representation of pines in young stands. Burning should not be applied until pines are at least 2 inches and preferably 3 inches d.b.h. (Little and Moore 1945). The burning should be repeated whenever the understory reaches 4 to 6 feet in height.

Planting. Extensive areas of poorly stocked, immature stands must be reinforced by tree planting if they are to be made productive. Experience to date is not sufficiently comprehensive to outline the details of this work at this time. It has been demonstrated that large vigorous planting stock, control of the rabbit population, and liberation cutting are essential to establishment (Wood 1936). Virginia pine seems the most promising of the species used for this type of planting.

Slash Disposal

Pine slash constitutes a moderately high fire hazard. It is resinous, decomposes slowly, and dries out rapidly because of the dryness of

the site. These conditions make it inflammable for a long period. The hazard drops noticeably in 2 or 3 years, when the needles have fallen, but the slash is somewhat inflammable for at least 10 years. Hardwood slash decomposes more rapidly.

There is no available evidence to show what effect slash may have on reproduction.

The method of complete piling and burning of the conifer slash is essential unless some form of special protection can be applied, in which case partial piling and burning is adequate.

Disease and Insect Problems

Insects and diseases are of minor importance in the yellow pine types. Shortleaf and pitch pine are attacked by the *southern pine beetle*, but serious damage is restricted to small localized areas. Intermittently a sawfly defoliates the pines over extensive areas.

Rot occurs chiefly in hardwoods that have been wounded by fire. Loss of merchantable timber occasionally runs high.

Control of the southern pine beetle is best accomplished by cutting the infested trees and then peeling the bark from the felled trees and burning it. Only in acute attacks is this necessary.

Fire protection eliminates the cause of infection of trees by rot-producing fungi.

Control of Animal and Logging Damage

Control of the deer population, as outlined for the oak types (see p. 100), is particularly important in the pine types, especially the pitch pine type, because of the extent to which pine reproduction is damaged (Frontz 1930, Illick and Aughenbaugh 1930).

Logging seems to present no problems of special importance.

SHORTLEAF PINE–OAK TYPES

Although of considerable importance in the oak region, the shortleaf pine–oak types (shortleaf pine–post oak, shortleaf pine–white oak, shortleaf pine–southern red oak–scarlet oak types) have not been carefully studied. According to our present knowledge, these types can be handled best by adhering to the general principles outlined for these types in the southern Appalachian region (pp. 175–181).

Where markets for pulpwood are near by, thus giving added value to the pines, conversion of the shortleaf pine–oak types into a pine type probably has considerable merit. Conversion on a fairly large scale with 2-year seedlings of pitch, shortleaf, and loblolly pine and 3-year seedlings of eastern white pine in New Jersey has been successful (Moore 1936). Cleanings must follow the planting in order to reduce the competition from oak sprouts.

BLACK ASH–AMERICAN ELM–RED MAPLE TYPE

Cutting and Planting

The composition and character of the forest are as follows:

Importance.
- Area—Major, but there are few extensive tracts.
- Commercial Value—Low.

Sites Occupied—Moist to wet mucks and shallow peats in swamps and depressions (Committee Report 1932).

Associated Species.
- Major—Red maple (generally predominates), American elm, black ash, pin oak, swamp white oak, yellow birch, gray birch, black tupelo, sycamore.
- Minor—White ash, slippery elm, rock elm, hemlock, bur oak.

Place in Succession—Climax type.

The stands are chiefly even-aged second growth, most of them being between 20 and 50 years old. Although moderately well stocked, they yield mostly low-grade products, defects being common even in relatively young stands.

In the few mature stands that are well stocked with advance reproduction red maple predominates.

The establishment of reproduction after any type of cutting is usually prompt and in generous quantity, but unless numerous seed trees of other species are retained it is likely to be composed chiefly of American elm, red maple, and yellow and gray birch. All species sprout freely, but those previously named reproduce more abundantly than their associates because of their prolific seed production, their wide dissemination by wind, and their lack of rigid seed-bed requirements—a moderate amount of moisture is the chief requisite.

If seedling reproduction of the oaks or ashes does get started, it quickly encounters serious competition from sprouts of all species and

the faster-growing seedlings, particularly red maple. American elm seedlings make rapid growth, but they, also, are soon dominated by the red maple. The natural tendency in the development of the stand to pole and young-timber size is toward a domination by red maple and American elm.

The wetness of the site and the shallow root development of many of the species, notably the elms, make windthrow a serious matter. Windbreakage is a common form of damage in mature stands because of the prevalence of rot.

The black ash–American elm–red maple type is difficult to manage profitably because of the preponderance of group 2 and group 3 species and the susceptibility of the stands to damage. Definite economic facts to serve as a guide in the silvicultural treatment of the type are lacking.

In view of the lack of a definite basis for recommending specific measures for this type, only general suggestions will be made. It is obvious that intensive silviculture does not pay. Therefore, clearcutting, followed by cultural operations generally in the form of improvement cutting or thinning, is suggested. Should the reproduction following cutting be composed of a large proportion of valuable species —swamp white oak, white ash, and yellow birch—cleanings should be substituted for the improvement cuttings.

Slash Disposal

The generally damp condition of the site, causing rapid decomposition of the slash and keeping its inflammability low, reduces the fire hazard of the slash, even though the slash volume is generally great, owing to crude utilization. These facts and the relatively low values at stake are the basis for recommending that the slash be left on the ground untreated.

Disease and Insect Problems

Trunk rot is the primary disease problem. Red maple and gray birch are very susceptible to attack by rot-producing fungi and therefore suffer most severely. Sprouts of any species are generally defective. Forest insects are no problem in the black ash–American elm–red maple type.

Increasing the representation of the least susceptible species and the number of trees of seedling origin by cultural operations is the most practical means of controlling the loss of wood by decay.

HEMLOCK TYPE

Cutting and Planting

The composition and character of the forest are given below.

Importance.
  Area—Minor.
  Commercial Value—Moderate to high.
Sites Occupied—Cool, moist sites, especially north slopes and along streams boxed in by abrupt slopes, particularly in Connecticut and New York.
Associated Species.
  Major—Hemlock, predominant or occasionally pure, chestnut oak, northern red oak, American beech, sugar maple, and yellow birch.
  Minor—American basswood, red maple, black cherry, white ash, eastern white pine, sweet birch.

All hemlock stands are second growth. Those having few hardwoods in mixture are usually even-aged, and those with numerous hardwoods in mixture are more often uneven-aged, the hemlock usually occurring as an understory. Hemlock stands tend to be dense, but various destructive forces have prevented this normal development except in small patches. Because of its exacting site requirements, the hemlock type never occurs uninterruptedly over a large area.

Advance reproduction of the more tolerant hardwoods and hemlock is generally abundant in stands that have not been damaged recently by fire or grazing. Because of the prevalence of such damage, stands well stocked with reproduction are not numerous. Too sudden exposure of advance reproduction, such as could develop from overcutting, causes serious mortality of seedlings from sun scalding (Merrill and Hawley 1924).

Hemlock is a good seed producer, a good seed crop occurring every 2 or 3 years. Consequently, if seed trees are retained, seed is not a limiting factor in regeneration. An overhead canopy that rather completely shades the ground, thus conserving soil moisture, moderating soil temperature, and protecting the seedlings from the direct rays of the sun, is essential to successful establishment of hemlock seedlings, because the shallow roots and tender tissues are very sensitive to drought and exposure (Merrill and Hawley 1924). When these environmental conditions are created by cutting in the spring after a seed crop, reproduction is usually successful.

With an available source of seed the hardwoods reproduce well regardless of the character of the overhead canopy. Sweet birch is often particularly aggressive in reproducing in hemlock stands. Ordinarily reproduction is abundant within a few years after cutting.

The hardwood seedlings grow faster than hemlock seedlings; thus they soon overtop the latter under natural development. The hemlock being a very tolerant tree suffers little mortality when forced into an overtopped position although its growth is impaired. Nevertheless, it has a high recuperative capacity after release, growth being two to three times as fast after as before release (Marshall 1927, Merrill and Hawley 1924).

The hemlock is seldom windthrown, even when a tree is left isolated by cutting, because its root system, although shallow, is widespreading, thereby giving the tree ample anchorage. The associated hardwoods are deeply rooted and therefore are not susceptible to windthrow.

Data on the economic aspects of managing hemlock stands are meager. The growing of hemlock promises to be as profitable as the growing of most timber crops in the oak region because of its rapid growth, its ease of establishment, and its marketing advantages. Hemlock stands yield twice as much wood volume in 80 years as oak stands and 50 to 60 per cent as much as eastern white pine (Merrill and Hawley 1924). The local demand for hemlock dimension-lumber is fairly good, because locally grown second-growth white pine yields low-quality lumber, and spruce is in such great demand for pulpwood that little of it is converted into lumber; therefore, hemlock lumber has little competition from local softwoods. Western softwoods offer greater competition.

The relative commercial rating of the hardwoods that occur in mixture with the hemlock is the same as that given for the oak types (see p. 89).

Only by partial cutting—the shelterwood method in even-aged stands, and the selection method in uneven-aged stands—can the hemlock type be perpetuated. The cutting should be as light as is economically feasible; every effort should be made to maintain a canopy of at least 50 per cent.

Improvement cuttings rather than cleanings should be applied to young hemlock stands because of the financial advantages of the former and the fact that the hemlock will persist in the stand. The better hardwoods, particularly group 1 species, and hemlock should be favored in all cultural operations. The improvement cuttings should

attempt to maintain a fairly open stand on shallow soils in order to prevent heavy mortality of the hemlock from drought (Stickel 1933).

Slash Disposal

The heavy volume of slash resulting from cutting, the relatively high inflammability of the slash for several years, its possible interference with the establishment of reproduction, and the high susceptibility of hemlock to damage by fire at all stages during its life make piling and burning of all hemlock slash imperative. Hardwood slash can be left untreated.

Disease and Insect Problems

No special precautions need be taken against insect and disease attacks because hemlock is relatively free of serious insect and disease pests (Spaeth 1928, Spaulding 1914).

Control of Animal and Logging Damage

Moderate grazing of hemlock stands during the reproduction stage is an effective means of increasing the proportion of hemlock to hardwood (Lutz 1928). Protection from deer is essential to survival of hemlock seedlings since they are more susceptible to damage than the hardwoods.

The chief problem in controlling logging damage occurs in stands in which the hemlock occurs as an understory. Great care must be taken in felling that trees fall into the more open parts of the stand.

BEAR OAK TYPE

Cutting and Planting

The bear oak type is characterized by the following:

Importance.
- Area—Major, especially in Pennsylvania and New Jersey.
- Commercial Value—Worthless, except possibly for game.

Sites Occupied—Chiefly pine-oak sites that have been repeatedly burned.

Associated Species.
- Major—Bear oak (sometimes pure).
- Minor—Pitch pine, eastern white pine, shortleaf pine, chinquapin, American chestnut, chestnut oak, black locust, red maple, sassafras, black tupelo.

Place in Succession—A temporary type, succeeded under fire protection by aspen, various oaks, pitch pine, shortleaf pine, or any combination of these (Committee Report 1932).

The bear oak stands are even-aged second growth, frequently very dense. The trees are seldom over 4 or 5 inches d.b.h., of poor form, defective, and unthrifty.

Photograph by Pennsylvania Department of Forests and Waters.

Fig. 20. Bear oak takes possession of areas that have been severely burned. Such sites are often so badly deteriorated that planting does not pay. Natural regeneration is a very slow process.

Only in stands that have had protection from fire for several years is there any advance reproduction, which is composed of species that originally occupied the site, but dominated by the low-value hardwoods. Where fires continue to burn over the land, bear oak regenerates much more successfully than any of its associates and thereby maintains its dominance of the stand (Fig. 20). Even with fire protection the process of natural conversion to a forest type containing a predominance of the higher-value species is slow because of the severe competition from the bear oak.

Windfall is unimportant in the bear oak type.

The bear oak type is practically worthless commercially. An income from the land is dependent upon the replacement of the bear oak by

species that have commercial value. Natural conversion is slow; therefore income is long deferred (Byers 1926, Perry 1922). On the other hand, complete artificial conversion is costly, $25.00 to $30.00 per acre in some cases, and the results questionable, especially where site deterioration due to frequent fires has been serious (Byers 1926).

Because the prospect of satisfactory results is uncertain and the income long delayed in the management of the bear oak type forest, landowners will generally find it best to expend their efforts in silviculture on other forest types and to place dependence for an improved stand largely in good fire protection. Cleanings should be made to hasten the conversion process but not until the reproduction of the more valuable species is large enough to compete with the profusion of bear oak sprouts that follow cutting.

If it is desired to promote the conversion process by planting, tree planting should be confined to the openings in the stand, where the trees are likely to survive and grow successfully without cleaning. According to the results of experiments in Pennsylvania, planting on freshly burned lands also holds promise of being successful (Byers 1926).

Problems in slash disposal, disease and insects, and animal and logging damage do not occur in the bear oak type.

EASTERN REDCEDAR TYPE

Cutting and Planting

This type has been referred to by Lutz (1928) as the redcedar–gray birch association. It is characterized by the following:

Importance.
- Area—Minor, but increasing by natural establishment in abandoned pastures and fields.
- Commercial Value—Moderate.

Sites Occupied—Dry uplands, particularly abandoned fields and pastures.

Associated Species.
- Major—Eastern redcedar, usually predominant, sometimes pure, and occasionally with gray birch strongly represented.
- Minor—Red maple, sweet birch, flowering dogwood, various oaks.

Place in Succession.—A temporary type succeeded by one of the oak types.

The eastern redcedar type is chiefly uneven-aged, although some stands are even-aged. The stands vary in stocking from the open

stand, in the process of establishment, to the fully stocked almost mature stands. There is an equally wide variation in age.

Advance reproduction, composed chiefly of hardwoods, is present only in the older stands, where improvement of the site due to a forest cover has been sufficient to allow the hardwoods to become established successfully. Advance reproduction is seldom, if ever, complete by the end of the first cedar rotation.

The establishment of subsequent reproduction depends on the presence of seed treees on the area to be reproduced. Heavy cutting encourages the establishment of abundant reproduction of gray birch, a species commonly abundant in the original stands. The advance reproduction, owing to its greater height, has a distinct advantage over the newly established gray birch seedlings; consequently the competition from the latter does not seriously affect the ultimate composition of the stand.

Windfall is of no consequence in the redcedar type. Windbreakage is likely to be serious in the gray birch when it becomes defective at maturity.

Although the eastern redcedar is a valuable tree for certain special products, such as fence posts and cabinet wood, its relatively slow growth, the long rotation required to grow it to lumber size, and the difficulty in maintaining it as a type militate against the perpetuation of the redcedar type.

In view of the foregoing, the objective in managing the eastern redcedar type should be its replacement by an oak type. Since the majority of the stands are understocked, it is generally impractical to attempt to direct the change in composition by improvement cuttings. Instead, it is more economical to postpone any treatment until the stand reaches silvicultural maturity, at which time all mature trees should be cut. It is unnecessary to follow this with cleanings because of the weak competition from low-value species.

Slash Disposal

Close utilization makes the slash volume light and the slash fire hazard low. Its light volume implies little, if any, interference with reproduction, although there are no data to demonstrate this. The logical conclusion is that slash should be left untreated.

There are no problems in disease and insect control or animal- or logging-damage control that require special attention.

WHITE AND RED PINE TYPES

A brief discussion of certain aspects of silvicultural practice for the white and red pine types is presented here, because certain problems (which do not occur in the New England white pine region) in these types, requiring special treatment, are known to exist in at least parts of the oak region. For the major practices to be applied to the white pine type, reference should be made to the New England white pine region (pp. 52 to 64). The discussion that follows is confined to the establishment of new stands and management of immature plantations.

These two types occur chiefly as plantations, most of the stands being under 45 years old. They occupy land that originally supported stands of oak which were removed to make way for agriculture, which was subsequently abandoned.

Hawley and Lutz (1943) believe that conifers should be grown for only one rotation to be followed either by hardwoods or mixtures of hardwoods and conifers which seed in.

Thinning

Experience with crown thinning in southern Connecticut in 26- to 38-year old white pine stands thinned for the first time has demonstrated that, unless the work is carried on under favorable conditions with experienced labor, the cost of the operation is greater than the returns from the sale of the products removed (Clapp 1936). Even with favorable working conditions profits will be small. Crown thinning, which leaves average openings in the stand of 10 feet, applied at intervals of 5 to 10 years, appears practical of application in southern Connecticut. Openings should be large enough to maintain a 35 to 40 per cent live-crown ratio (Hawley and Lutz 1943).

Thinnings, the first at an age of 20 to 25 years in plantations with a 6-by-6-foot spacing of the trees, should be applied at intervals of 3 to 5 years between the twentieth and fortieth years and at intervals of 5 to 8 years between the fortieth and sixtieth years (Hawley and Clapp 1935). Thinning is important in controlling the tympanis canker (see below).

Pruning

Pruning studies in both white and red pine stands in southern Connecticut demonstrate that the same general principles recommended for the New England white pine region apply to the oak

region. Briefly, pruning 72 to 120 trees per acre in white pine plantations to a height of approximately 17 feet in two or three operations has been calculated to yield a net profit of $16.42 per thousand board feet (Hawley and Lutz 1943). The trees selected for pruning in either white or red pine stands should be straight, fast-growing dominant or codominant trees, except in badly weeviled white pine stands, where the selection should be made from the better trees in the intermediate and codominant crown classes. A handsaw is best for pruning the lower part of the bole and, when used with a ladder, is superior to a pole saw for pruning above 7 feet, since it makes a better cut and there is practically no difference in cost (Hawley and Clapp 1935). A tool consisting of a two-edged blade mounted on a pole has been used effectively for pruning above 7 feet (Rich 1935), and the pointcut pruning shears have proved their worth for pruning below 7 feet (Hawley and Clapp 1935). Further experimentation with these tools is necessary before they can be recommended as superior to the "handsaw-with-ladder" method. Red pine can be pruned at less cost than eastern white pine.

Tympanis Canker

Control of the European pine shoot moth and the tympanis canker in red pine plantations is essential to success in growing this tree. The tympanis canker enters the tree through dead lateral branches and attacks the cambium, causing a heavy exudation of resin, disfigurement, some decay, and occasionally outright death of the tree by girdling (Hansbrough 1936). In view of the indications from a study of the tympanis canker that the disease is worst south of the optimum range of red pine, in pure stands of red pine, and on poor sites (Hansbrough 1936), the author suggests that the selection of sites for new red pine plantings be made with care. Certainly caution should be exercised in planting on poor sites in the southern part of the oak region. Mixture of red pine with white pine and a spacing of 8 by 8 feet are further precautions that should be taken (Hansbrough 1936). Deficient soil moisture appears to be an important factor in severe infections. In addition to discretion in establishing new red pine plantations, pruning and thinning should be applied to existing stands as a preventive or control measure.

European Pine Shoot Moth

The European pine shoot moth has in recent years done considerable damage to red pine. It destroys the terminal bud, thus causing the

development of a crooked stem in trees under 30 feet tall (Friend 1931). Since it spreads slowly it can be controlled by cutting and burning the infested tips. Annual treatment until the infestation is eliminated is essential to effective control. This is costly. Planting of red pine should be discontinued where this pest is known to occur.

Control of Animal Damage

Although the wisdom of grazing young pine plantations has been questioned (Cope 1925), it appears from the evidence at hand that in plantations supporting a considerable amount of palatable vegetation grazing by cattle and horses is advantageous (Forsling 1925, Stickel and Hawley 1924, 1925). The number of animals must be carefully regulated and their distribution over the area must be uniform.

In Pennsylvania, where the population of deer is large, young plantations must be given protection. Fencing the newly planted areas or covering the planted trees with slash are effective but not very practical measures. Some control can be secured by a reduction in the deer population, which in reality is a protection to the deer themselves. The development of a satisfactory repellent for use on the trees appears to be the most practical solution (Clepper 1931).

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4 · *Allegheny Hardwood-Pine-Hemlock Region*

DESCRIPTION AND HISTORY

Location and Landownership

The Allegheny hardwood-pine-hemlock region occupies most of southern New York, northern Pennsylvania, and the central highland section of Pennsylvania. The region includes approximately 8,000,000 acres of forest land. National forests embrace 463,000 acres (in 1948) and probably will ultimately occupy nearly 1,000,000 acres. State-owned lands include approximately 1,000,000 acres. It is likely that at least 1,500,000 acres ultimately will be owned by the states. A considerable proportion of the forested area is in large tracts.

Physiographic Features

The topography is chiefly hilly to mountainous. The Allegheny Mountains and the northern extension of the Appalachians are the outstanding topographic features of New York and Pennsylvania, respectively. Most of the region lies at an elevation of 1500 to 2500 feet. The topography is rather rough, the slopes being short and steep. The ridges are fairly well rounded because of long-time erosion.

With the exception of central Pennsylvania, most of the region has been glaciated. In the glaciated section the soils are diversified and contain considerable loose stone and boulders. Most of the soils are fairly fertile and are of a sandy loam texture.

There are numerous streams, which allow for adequate drainage. These flow either into the Atlantic Ocean, the Gulf of Mexico, Lake Erie, or Lake Ontario. Numerous lakes add variety to the physiographic features in the glaciated sections.

Climatic Features

The climate is characterized by a moderate to abundant, well-distributed precipitation, a humid atmosphere, frequent changes in weather, and a marked contrast between seasons.

Mean annual precipitation, although varying from about 30 to 53 inches, ranges from 35 to 45 inches over the major part of the region. The wide range is due chiefly to differences in elevation. Distribution of precipitation is generally good, except that late August or early September is usually dry. Although most of the precipitation occurs in the form of rain, snow usually falls irregularly between November and March. The average annual snowfall ranges from about 30 to 73 inches (Weather Bureau 1926).

The relative humidity is normally high. Not often does it fall below 60 per cent.

The mean annual temperature varies from about 43° to 54° F. The mean temperature for the month of July ranges from 65° to 75° F., and, for January, the coldest month, from 20° to 33° F. Short periods of very hot weather occur during the summer, when a maximum temperature of 100° F. or higher may be recorded. During the winter season, temperatures below zero have been recorded frequently. The lowest temperature on record is −32° F. The growing season for most of the region is approximately 5 months. Variations above and below this are related to differences in altitude.

Thunder storms are nearly always accompanied by considerable precipitation. The prevailing winds are from the north, except during July, and are usually of moderate velocity. Occasional high winds occur locally, the highest wind velocity on record being 72 miles per hour (Weather Bureau 1926).

Development of Lumbering

Lumbering in the Allegheny hardwood-pine-hemlock region started at an early date. There was a rapid development soon after 1800, particularly between 1830 and 1840. By 1860 this region led the nation in lumber production. Only 10 years later the better grades of white pine lumber were being imported from Michigan. The maximum lumber production was reached in 1889, the large production of that year coming from the cutting of hardwoods and hemlock as well as

pine. Except for a few small isolated remnants of the virgin forest, the region has been entirely cut over.

The early cutting in the region was largely for white pine. Later, as a good market for hemlock bark developed, this species was cut for its bark only. The logs were usually left in the woods to rot. Somewhat later, hemlock logs were utilized for lumber and pulpwood. The hardwoods came into use at about the same time. With a market for almost all species, cutting removed practically all tree growth from the forest.

The Effect of Past Practices

The first cutting removed eastern white pine that had been thoroughly culled from the stands very soon after the Civil War. The next culling, covering a very much larger acreage, removed the black cherry and a few other hardwoods of high grade, but particularly the hemlock. Since the rise of the hardwood distillate industry in the present century, very close cutting has been the rule, first for saw-log and similar products and then, within a season or two, for the chemical wood. In the absence of fire after such cutting in hardwood stands, a surprisingly good stand of second growth usually developed. The abundant advance reproduction that was generally present escaped serious injury since horse logging was usually employed (Fig. 21). On the other hand, where fire consumed the slash, an inferior stand of quaking aspen or pin cherry took possession of the land. White pine stands have not reproduced successfully on cut-over land, but there are some good second-growth stands on old fields.

Practically all stands that were culled in the early cutting have since been cut over closely so that the existing forest is chiefly second growth or third growth with a sparse scattering of residual trees.

Where the land surface had a gentle gradient a considerable acreage of forest land was cleared for agricultural use. After being used for the production of farm crops for some time, many of these lands were abandoned as agriculture developed in the West. This farm-land abandonment is still in progress. Estimates for New York in 1931 placed the idle land unsuitable for agriculture at 4,000,000 acres (Rankin 1931).

Much land in state ownership has already been planted, both in Pennsylvania and in New York. This work has progressed on an increasing scale since about 1900. Additional impetus has been given to this reforestation program in the state of New York with the passage in 1929 of the Hewitt Reforestation Bill, which laid the groundwork

for the purchase and reforestation of abandoned farm lands over a period of 15 years with an appropriation of $20,000,000. Early in 1948, approximately 500,000 acres of land had been purchased and incorporated into the state's system of state forests. At the end of the 1947

Photograph by U. S. Forest Service.

Fig. 21. This stand developed chiefly from advance reproduction present at the time of cutting a northern hardwood stand 60 years previously. Only the hemlock and better hardwoods were cut. The large American beech in the center-right foreground is a residual tree.

planting season, 270,630 acres had been reforested, and another 100,000 acres supported natural stands.

THE FORESTS AND THEIR MANAGEMENT

The original as well as the present forest over the greater part of the region were dominated by northern hardwoods and hemlock. However, site variations caused other species to dominate locally, thus creating numerous forest types of secondary importance. Severe local wind storms and perhaps lightning fires temporarily created open sites that were quickly occupied by white pine and some of the less tolerant hardwoods, followed by the invasion of hemlock. In addition to the sugar maple–beech–yellow birch and other northern hardwood types,

the silviculture of which is described in detail here, there is a small acreage of various oak types, chiefly scarlet oak–black oak, chestnut oak, white oak–black oak–red oak, white oak, and red oak (oak region, p. 85), and of such temporary types as aspen (Lake states region, p. 332), pin cherry, bear oak (oak region, p. 111), and white pine–hemlock (New England white pine region, p. 45). The white pine–hemlock type was originally the most valuable commercial timber type of the region, but it failed to survive cutting and fire as well as some of the other types, with the result that it is now of secondary importance. On many burned areas it has been replaced by stands of low-value hardwoods (Wood 1932). Because of the lack of definite information on this type, its silviculture is not discussed here.

SUGAR MAPLE–BEECH–YELLOW BIRCH TYPE

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of Forest. The sugar maple–beech–yellow birch type, referred to locally also as the beech–birch–maple type (Illick and Frontz 1928), is discussed in detail because it is the most important of the northern hardwood types in this region from the area standpoint. The other forests are similar to it, differing only in species composition. Light fires apparently have favored the establishment of occasional pure stands of birches, as has windthrow.

Importance.
  Area—Major.
  Commercial Value—High.
Sites Occupied—Fresh, well-drained, fertile soils, chiefly at altitudes between 1000 and 2500 feet (Committee Report 1932).
Associated Species.
  Major—Sugar maple, American beech, yellow birch, sweet birch.
  Minor—Black cherry, white ash, pin cherry, American hornbeam, eastern hophornbeam.
Place in Succession—Climax type.

The stands are chiefly second growth. The older ones (40 to 50 years) contain some old trees of saw-log size, particularly hemlock, holdovers from the virgin forest (Fig. 21).

Composition is similar to that of the old-growth forest, except where fire has burned over the cut-over land, in which case it is changed to a greater or lesser degree. Stocking may be reduced and, in extreme

cases, successional development to a desirable composition may be very slow (Wilm 1936).

Bole form and pathological defects in some unburned second-growth stands are numerous, averaging 9.6 and 7.7 per cent, respectively, of the total number of trees (Hough 1937*a*) on one small area studied intensively. In this instance, bole-form defects were worst in American beech, black cherry, and sweet birch, which accounted for 20.0, 15.1, and 9.0 per cent, respectively, of the trees affected; and pathological defects were worst in American beech, hemlock, and sugar maple, which constituted 15.0, 13.2, and 12.8 per cent, respectively, of the trees infected.

Third-growth forests (resulting from the clearcutting of young merchantable stands) are composed chiefly of sprouts. Black cherry, pin cherry, red maple, eastern hophornbeam, and American hornbeam dominate the stand (Ostrom 1938).

Stands are chiefly even-aged and range from 1 to 50 years old.

Stand Regeneration and Development. *Advance Reproduction.* Culled stands generally support well-stocked understories consisting of advance reproduction, which was present before the culling, and subsequent reproduction, which arose after the cutting. The composition of the understory is similar to that of the original stand, except that sugar maple is somewhat more abundant.

Unmanaged, second-growth stands under 50 years old support little, if any, advance reproduction, whereas thinned stands support some seedlings. Since seed production increases rapidly after 50 years, seedling establishment in older thinned stands increases accordingly. Sugar maple dominates the reproduction, as illustrated by a 60-year old stand in Pennsylvania which supported 462 sugar maple, 14 American beech, 9 black cherry, and 51 striped maple seedlings per 100 square feet (Illick and Frontz 1928). The value of advance reproduction is emphasized by the fact that it suffers only about half as much mortality as subsequent reproduction (Hough 1937*a*).

Subsequent Reproduction. Subsequent reproduction becomes established in abundance after either partial cutting or clearcutting of the older second-growth stands, but there is a marked difference in its composition under the two methods. Clearcutting is followed by a reproduction stand composed largely of pin cherry, eastern hophornbeam, American hornbeam, red maple, and black cherry, the last two species being largely of sprout origin (Ostrom 1938). Partial cutting is followed by a reproduction stand composed of the species in the residual stand, with sugar maple most abundant. Cutting that re-

moves more than one-half of the merchantable volume of the stand promotes the development of subclimax species, if these species are in or near the area cut (Hough and Forbes 1943). Black cherry, white ash, and yellow-poplar are favored by group-selection cutting. Hemlock and white pine can reproduce only after partial cutting, since they do not sprout. A canopy of moderate density favors white pine establishment but does not allow for satisfactory seedling development. The seedlings are soon badly suppressed. The establishment of an adequate reproduction stand after partial cutting requires many years because of the heavy mortality of young seedlings, owing to low soil moisture during critical periods, competition from reserved trees, sprouts, and shrubs, and localized unfavorable seed-bed conditions, such as may result from dense hardwood or slow-rotting hemlock slash (Hough 1937*a*).

Clearcutting of culled or virgin old-growth stands is generally followed by an abundant stand of reproduction of valuable species, chiefly sugar maple and yellow birch (Cope 1935).

Development of Reproduction. Because of its rapid growth black cherry reproduction, particularly the stump sprouts, has a distinct advantage over its associates in either partially cut or clearcut stands (Hough 1937*a*, Ostrom 1938). This advantage is more significant in clearcut than in partially cut second-growth stands because of the greater abundance of black cherry reproduction, especially stump sprouts, in the former. Studies indicate that black cherry so dominates the stand that it ultimately constitutes over 50 per cent of the stand in third growth resulting from clearcutting. The poor form and defective character of black cherry stump sprouts make such stands definitely inferior.

The reproduction stand resulting from clearcutting of culled old-growth stands or partial cutting of second-growth stands has a good chance of developing into a satisfactory stand, because the fastest-growing elements, black cherry seedlings and sprouts and eastern hophornbeam seedlings, are minor components of the stand (Hough 1937*a*). Seedlings of all species make relatively slow growth, but sugar maple and white ash seedlings are especially slow growing. This is less of a handicap to the former, because it is tolerant enough to survive even though fast-growing hardwoods soon overtop it. Seedling sprouts make excellent growth, two to three times as much as seedlings. The conversion of sugar maple and white ash seedlings into seedling-sprouts should materially aid these species, because their growth would then be more nearly comparable to that of the reproduction of other species.

The birches and American beech are very sensitive to exposure in the sapling and pole stages, mortality among them often being high. Therefore, silviculturally they are weak elements in a stand.

Windfall and Glaze Damage. Although the trees of the sugar maple–beech–yellow birch type are windfirm, there is evidence that local windthrow apparently occurs during high winds.

Severe windbreakage is associated with glaze storms. Although infrequent in their occurrence, these storms, when accompanied or followed by wind, do tremendous damage (Downs 1938). The extent of glaze damage varies with age and condition of the stand, species composition, and site location, with particular reference to altitude and aspect. The glaze storm of March 1936, damaged 18.6, 37.9, and 68.4 per cent of the cubic foot volume of 10- to 20-year, 21- to 40-year, and culled old-growth stands, respectively, on a tract in Elk County, Pennsylvania. Black cherry suffered much heavier damage than any other species; and hemlock, with 4.8 per cent of the trees damaged severely, was affected much less than such moderately resistant species as sweet birch, red maple, yellow birch, American beech, and sugar maple, of which 15 to 16 per cent were severely damaged. Damage increased with increase in altitude and was greater on north and east slopes than on west and south slopes. Glaze-damaged trees are a real decay hazard, as pointed out in detail on p. 134.

Economic Basis

Although the market for pulpwood and chemical wood provides an opportunity for fairly complete utilization, management that is based on these products only cannot be the most profitable because of the uncertain and fluctuating character of the market, the higher value of saw logs, and the stand deterioration that is certain to develop from such practice (see p. 126) (Dana 1930). Birches, beech, and sugar maple are the preferred species for chemical wood because of their high yields of chemicals; the birches yield birch oil, for which a fairly good market exists; sugar maple stands yield maple syrup and sugar and excellent saw logs. The birches and sugar maple thus have the greatest all-round utility.

Black cherry, American basswood, white ash, and eastern white pine are as valuable as the foregoing species and, where markets for their special products exist, they have greater value per unit of measure. Red maple is inferior to any of the species named but is distinctly superior commercially to pin cherry, American hornbeam, eastern hop-hornbeam, and quaking aspen.

Rapid growth is inherent in eastern white pine (exceeds all other species), American basswood, black cherry, and white ash. This characteristic, together with high commercial value, makes these species especially valuable (Illick and Frontz 1928). However, black cherry must be kept in a dominant position if it is to survive (Hough and Taylor 1946). Sugar maple, American beech, and red maple make the fastest growth after release. Growth is affected by tree size and vigor, stand density, and volume of growing stock. The larger and more vigorous trees grow fastest. Removal of 38 per cent of the cubic-foot volume in one 40-year-old stand resulted in a 70 per cent (0.71 cord per acre per year) increase in growth of the treated portion of the stand over that of the untreated portion (Hough and Taylor 1946). In a stand of saw-log size annual growth per acre ranged from 250 board feet on a reserve stand of 2000 board feet to 350 board feet on a reserve stand of 8000 board feet (Hough 1943). Growth of young stands is most rapid during the first 60 years but continues at a moderate rate for 20 to 40 years longer. The production of saw logs increases rapidly after the sixtieth year, and by the eightieth year 80 per cent of the trees are of saw-log size. A rotation of less than 80 years for saw logs is impractical.

Application of Methods

Silvicultural practices that encourage the establishment of advance reproduction, provide stands composed of the maximum of commercially valuable species, maintain existing markets for chemical wood and pulpwood, encourage the expansion of saw-log markets, and give maximum protection against various destructive agencies must be employed if timber production is to be profitable. In general, these requirements imply: the employment of a rotation sufficiently long to produce saw logs and to provide an adequate seed supply for natural seedling reproduction; the systematic application of cultural operations that will improve the stand composition from the standpoints of commerce and protection (particularly against glaze and decay) (Fig. 22); and the avoidance of clearcutting until an adequate stand of reproduction is established.

Reproduction and Sapling Stands. Cleaning should be applied to reproduction and sapling stands only if there are enough commercially valuable trees to justify the cost (third-growth stands resulting from clearcutting of second-growth stands seldom have a satisfactory composition). The first cleaning should be made within the first 10-year period after the final cutting of the previous stand (Hough 1937*a*).

Because of the decay hazard, any clumps of multiple-stemmed sprouts that are not treated before the twentieth year should be either left intact or removed completely. A special effort should be made to rid the stand of the black cherry and red maple stump sprouts—the former species because of its inferior character and tendency to dominate the stand, and the latter species because of its high susceptibility to nectria

Photograph by U. S. Forest Service.

Fig. 22. Improvement cutting in a second-growth northern hardwood stand that contained scattered residual hardwoods. Approximately 12 cords of wood per acre were removed.

canker (p. 35) and, also, its tendency to dominate the stand. Breaking black cherry sprouts from the stumps for 2 or more consecutive years, in early summer just after the sprouts have completed their period of rapid height growth, is an effective and cheap method of ridding the stand of this material because of the usual failure of resprouting after the second treatment.

Hemlock and eastern white pine seedlings should be released with the objective of reducing the susceptibility of the stand to glaze damage by increasing the representation of conifers (Downs 1938). In each cleaning, fast-growing individual stems that are likely to cause an uneven canopy should ordinarily be removed as a protection of the stand against future glaze damage.

Unburned stands of poor composition, or understocking and burned stands in which the development of a desirable stand composition is slow, can probably be improved advantageously by planting either or both eastern white and red pine in the more open parts of the stands; 2-2 planting stock should be used (Wilm 1936), and cultural operations must follow the planting.

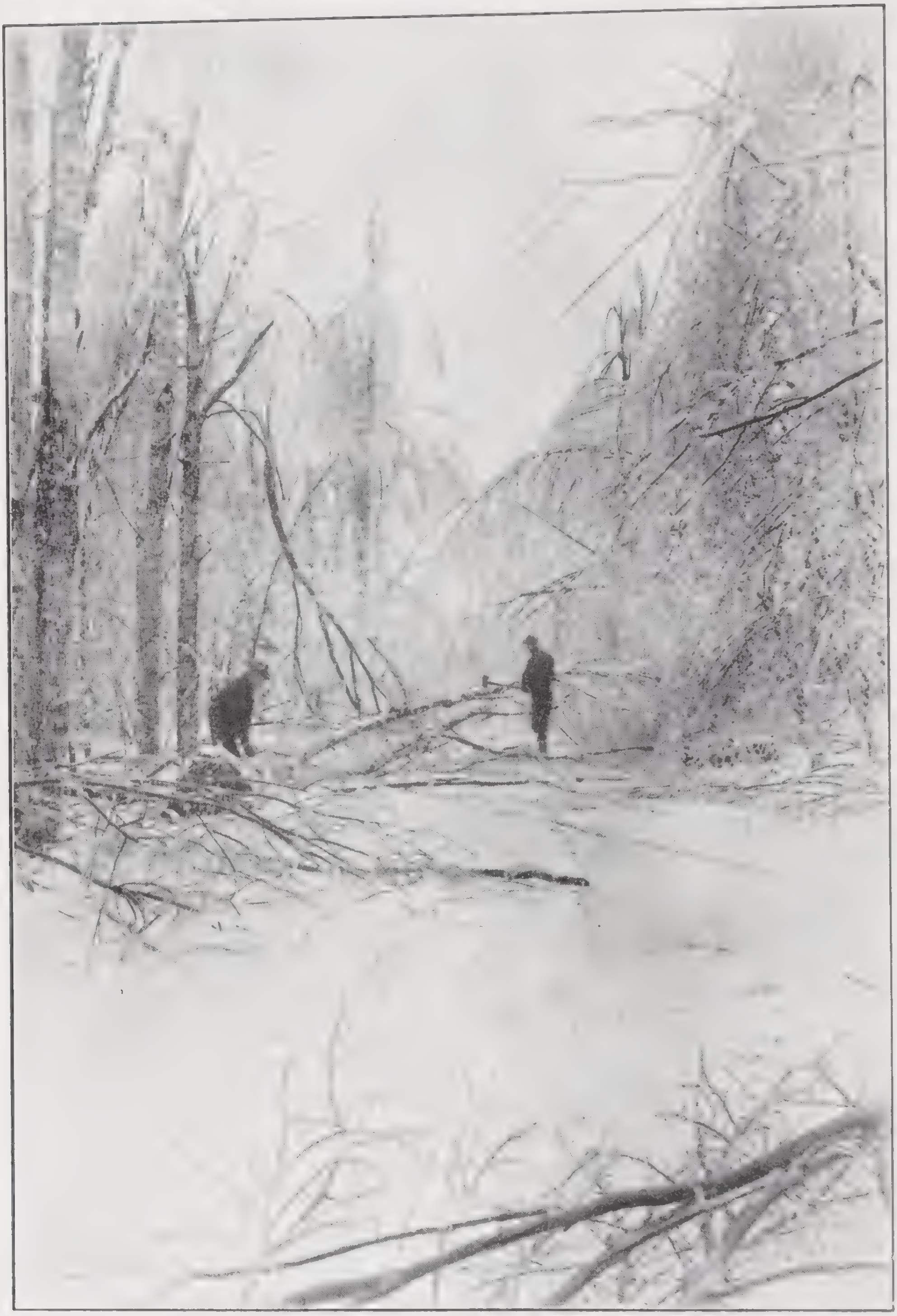
Young Mature Stands. Young mature stands that have been previously treated by thinning or improvement cuttings do not require any special treatment unless adequate advance reproduction has failed to become established, in which case heavier thinnings should be applied. Stands previously untreated must, by all means, either be thinned heavily, so that at least one-third of the total volume of the stand is removed in order to permit advance growth before final cutting by a shelterwood system, or be cut by the selection method (best for older stands) (Hough 1937*b*). When adequate reproduction is established and the stand contains a profitable number of saw-log trees, the final shelterwood cutting may be applied. At the time of this cutting it is advisable to lop off the advance seedlings of poor form (Hough 1937*a*). Subsequent treatment should follow that outlined for reproduction and sapling stands (p. 129).

In partial cuttings frequent light cuts maintain the best growth and produce the best quality of timber. Of the various degrees of partial cutting that have been recommended, one that removes no more than 40 per cent of the board-foot volume and removes no trees below 14 inches, unless crowded, produces the best results (Taylor 1946). Cutting of this type is likely to maintain sufficient canopy to provide the protection that the birches need. Emphasis should be placed on retaining as many trees as possible in the better vigor classes.

Group-selection cutting is most applicable when the highly defective trees occur in small groups rather than at more or less uniform intervals through the stand.

Culled Old-Growth Stands. Clearcutting is often the most practical method (not necessarily the best silviculture) for handling these stands, since it is a financial success and is usually followed by a well-stocked reproduction stand of desirable species (Cope 1935), except on some of the poorer sites. Defective holdover trees must by all means be disposed of. If the stand is not too decadent, partial cutting is advisable.

Choice of Species. In all cutting operations, care should be exercised in choosing the species that are to be retained in the stand. Because of their adaptability to the site and their varied utility, sound,



Photograph by U. S. Forest Service.

FIG. 23. Glaze storms sometimes do severe damage over large areas. In such cases stand-improvement measures should be applied as soon as possible to prevent additional stand deterioration. Proper regulation of stand composition may aid in making future stands less susceptible to damage by glaze storms.

straight sugar maple and sweet and yellow birch should generally be retained. Because the birches are very sensitive to exposure, stands in which they are to be encouraged *must* be handled very conservatively. Cutting adjacent to these species must be light. Seedling and seedling-sprout black cherry are highly desirable, as are American basswood, white ash, eastern white pine, and hemlock. At the higher elevations and on north slopes hemlock and sugar maple should be given every opportunity to develop in order to increase their representation in these stands as a protection against glaze damage (Downs 1938) (Fig. 23). Beech and red maple should also be favored.

Planting. Abandoned farm lands, of which there is a considerable acreage, represent the major planting problem. Where soil deterioration has not been severe, eastern white pine (if protected from deer, white pine weevil, and blister rust) and Norway spruce can be planted to advantage. Where soil deterioration has been severe, red pine is more likely to succeed.

For sites with a heavy soil or a rank ground cover, 3-year transplants are superior to seedlings, although preliminary investigations indicate that 3-year-root pruned seedlings may be satisfactory (Committee on Technical Practices 1932, Rankin 1931). Seedlings must be used where planting is done by machine. Spring planting is preferable to fall planting.

Hardwoods should be spaced 10 by 10 feet and conifers 6 by 6 feet. Conifers (except white pine, which must be spaced closely to control the white pine weevil) can be spaced more widely, but such practice necessitates more intensive treatment of the young stand in order to produce quality timber.

Slash Disposal

The generally close utilization makes the quantity of slash relatively small. Four- to five-year-old hardwood slash has decomposed sufficiently to reduce the slash fire hazard below the danger point. Hemlock slash does not decompose as rapidly but is seldom present in sufficient quantity to increase the fire hazard materially.

Slash apparently has an adverse effect on the establishment of reproduction, but this is confined to small patches of dense slash (Hough 1937*a*).

Treatment of slash should be limited to the scattering of densely accumulated slash that would interfere with regeneration, except in areas of extremely high hazard where partial piling and burning should be used.

Disease and Insect Problems

Ecological Basis

Decay is the chief disease problem. It is most prevalent in American beech and hemlock, particularly the "holdovers," in which it affects 15 and 13.2 per cent, respectively, of the trees of these species being infected (Hough 1937*b*). Sugar maple and yellow birch, of which 12.8 and 8.8 per cent, respectively, have pathological defects, rank next in susceptibility. Red maple is highly subject to the nectria canker. Next in order of susceptibility (high to low) are the pine cherry, sugar maple, sweet birch, yellow birch, black cherry, and American beech (Hough 1937*a*).

All ice-damaged trees represent a decay hazard, but its extent depends on the species, the character of damage, and other factors (Campbell and Davidson 1940, Spaulding and Bratton 1946). Three to four years after a severe glaze storm in Pennsylvania, it was evident that, where top wounds were 3 inches or less in diameter, decay would extend not more than 2 to 3 feet below the break in black cherry and less than 6 inches in sugar maple. Such trees seem to be good risks for saw-timber production, provided the breaks are confined to branches and the upper part of the main stem and are accompanied by vigorous crown regeneration. On the other hand, large wounds that dry on the surface and are not thoroughly decayed by saprophytes may eventually become infected by typical wood rotters. Trees with such wounds are poor risks.

In central New York recovery of crowns of glaze-damaged trees by sprouting was poor for sugar maple and American beech but was good for white ash and American basswood (Spaulding and Bratton 1946). Sunscald was severe in trees whose crowns did not recover, and the sunscalded areas were frequently invaded by sap rot. Sap rot and heart rot developed in many trunk wounds. Although basswood and white ash are better risks than sugar maple and American beech, none are satisfactory.

Various insects invade glaze-damaged and other weakened trees. Where susceptible trees are numerous, insect epidemics are likely to develop.

Control Methods

Control of disease and insects pests is synonymous with good silviculture. Cleanings and improvement cuttings as outlined on p. 129

minimize the damage from these sources. Prompt attention should be given to glaze-damaged stands, in so far as practical, in order that they may not become centers of infection for adjacent stands. Apparently lightly damaged trees can be retained to produce saw logs, but severely damaged trees can seldom be left for more than 10 to 15 years, and if their crown recovery is poor they should be cut as soon as possible.

Control of Animal and Logging Damage

Inasmuch as grazing by domestic livestock in small wooded areas, when continued for a period of years, causes damage to seedlings, injures the roots of shallow-rooted trees such as American beech and hemlock, and changes stand composition, pasturing should not be allowed (Lutz 1930). Deer populations must also be kept under control.

Porcupines may be controlled by means of strychnine-treated bait wherever damage to a stand, evidenced by numerous bole injuries, is serious. Such work must be carefully done to avoid death of other wildlife.

In the absence of research on logging damage, no specific recommendations on its control are presented. Of particular importance is the handling of "holdover" trees. Their disposal by girdling or poisoning, especially when they are very defective, is a sane method of preventing serious damage to the remainder of the stand. Sanitation measures to remove trees badly scarred or crippled in logging should follow logging operations.

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5 · *Southern Appalachian Region*

DESCRIPTION AND HISTORY

Location and Landownership

This region occupies the entire southeastern mountain and highland areas south of Pennsylvania. The following portions of the various states are included: eastern West Virginia, Kentucky, and Tennessee; western North Carolina, South Carolina, Virginia, and Maryland; and northern Georgia and Alabama (Fig. 1). The area of potential timberland is 60,771,000 acres (Frothingham 1931). This constitutes 59 per cent of the total land area. Of the timberland area, approximately 21,000,000 acres lie in the mountains and 40,000,000 acres in the plateaus. The forested section of the plateau region is largely in farm woodlands of 50 acres or less. The farm woodlands constitute approximately 30 per cent of the forest area of the mountains. The woodlands in the mountains are generally larger than those of the plateau section.

On June 30, 1947, there were eleven national forests with an aggregate area of approximately 5,500,000 acres. This area is being expanded through the acquisition program of the Federal Government. The national parks will probably ultimately cover 700,000 acres, mostly in North Carolina, Tennessee, and Virginia. Other publicly owned lands occupy only a small acreage. The aggregate of state forests, state parks, and municipal and county forests and parks is less than 100,000 acres. Approximately 92 per cent of the forest-land area is privately owned.

Physiographic Features

Physiographically, the region is divided into four natural divisions from east to west, namely, the Piedmont Plateau, the Appalachian Mountains, the Appalachian Valley, and the Cumberland and Allegheny Highlands. The topography is diversified, and the range in

altitude is wide. The Piedmont Plateau forms a broad strip along the east at an elevation of 500 to 1000 feet. The plateau has a gentle gradient to the east but is hilly and rolling. It is narrowest in the north, gradually widening to the south. The Piedmont Plateau breaks rather abruptly into the Appalachian Mountains, the most important ranges of which are the Blue Ridge and the Great Smoky Mountains. These mountains are fairly high, attaining their greatest height in North Carolina, where Mt. Mitchell has an elevation of 6684 feet. The southern Appalachians are broadest in the south, gradually narrowing in Virginia to a single range, the Blue Ridge. The highest points in the northern extension of the Blue Ridge are approximately 2500 feet. The elevation gradually increases to the south, where a few peaks reach nearly 5000 feet. Other prominent mountain ranges in the southern Appalachian system are the Unakas, the Great Smoky Mountains, Iron Mountains, Nantahala Mountains, Black Mountains, and the Pisgah Range. Most of these run in a southwest-northeast direction, but there are numerous cross ranges bearing otherwise. The Unakas and Great Smoky Mountains attain the highest elevations, their average being around 5000 feet, with a number of peaks over 6500 feet.

The southern Appalachian system has never been glaciated, but the slopes have been smoothed by erosion. Many of the ridges are steep, but there are few sharp ridges or cliffs, except near the summit of major ridges, where bare rock and cliffs occasionally form very broken topography. The slopes are steep and in some sections are broken by numerous streams. Directly west of the Appalachian Mountains is the Appalachian Valley, a composite of the Shenandoah and Tennessee Valleys, which ranges in altitude from approximately 700 feet to 2000 feet. This is a broad fertile valley winding its way between the southern Appalachian system on the east and the Allegheny and Cumberland Mountains on the west. The Allegheny and Cumberland Mountains contain peaks having an elevation of 2000 to nearly 5000 feet, and, in general, they are less rugged than the Appalachians.

The Allegheny and Cumberland Plateaus, forming the western portion of the region, have elevations of 1000 to 2000 feet above sea level. These plateaus are approximately 50 miles wide in the northern part, but they narrow abruptly at their southern extremity. They have a gradual slope toward the west.

With the diversity of geological formations and the accompanying variation in structure and elevation, the soils are equally diversified. The soils of the Piedmont Plateau, of residual origin, are generally

referred to as the "red clay land." The surface soils are chiefly loams or clays with scattered areas of sand, and the subsoil is often a red clay. These soils are subject to excessive erosion when cleared. The largest area of the most fertile soils occurs in the Appalachian Valley.

The soils in the mountains are extremely varied in character. The best exist in the coves, along streams, and on moist benches and northerly slopes. In these situations the soils are usually deep and friable, contain a large amount of humus, and have a loamy texture. In contrast, those of the upper slopes and ridges are usually sandy, shallow, and lacking fertility. Most of these soils contain large rock fragments and are frequently underlain at a shallow depth by bed rock.

The topography is dissected by numerous streams, which provide free drainage for the entire region. In the higher mountains the streams are small, too small to be valuable in transporting forest products. Particularly in the mountainous sections, streams have a steep gradient, in some cases falling as much as 600 to 700 feet per mile. The summit of the Blue Ridge is the eastern continental divide. Watersheds draining to the east from the Blue Ridge enter the Atlantic Ocean, whereas those draining to the west flow into the Mississippi River through the Tennessee or Ohio Rivers.

Climatic Features

The climate is characterized by an abundant, well-distributed precipitation, a humid atmosphere, a moderately long growing season, and relatively mild temperatures throughout the year. The climate varies locally because of marked differences in altitude and location in relation to the paths of the main storms.

The average annual precipitation for most of the region is between 45 and 55 inches, although in excess of this amount in some sections, particularly in the high mountains (Weather Bureau 1926). The precipitation is well distributed throughout the year, the average precipitation for the "driest" month—November—being about 2½ inches. Precipitation during December, March, and April is also lower than average. With the exception of a few localities, the maximum precipitation occurs during July, the average total precipitation during this month being between 5 and 6 inches. Since precipitation is generally copious throughout the year and heaviest throughout the summer, the occasional dry summer is the feature that has silvicultural significance. Snow in appreciable quantity is confined to the higher mountains.

Below 1000 feet the average annual snowfall is less than 1 foot, from 1000 to 2000 feet it varies from 31 to 55 inches, and in the high mountains snow accumulates to a depth of several feet.

Because of the proximity of this region to the Atlantic Ocean, the atmosphere is humid. Although relative humidity is generally above 65 per cent, it does fall below 20 per cent rather often during certain periods.

The climate is relatively mild, except at the highest elevations. The mean annual temperature at elevations below 4000 feet is between 50° and 62° F. at most points. The mean temperature for July, the hottest month of the year, is between 69° and 77° F. (Weather Bureau 1926). The lowest mean monthly temperature, occurring in January or February, varies from 30° to 40° F. Nearly all sections of the region occasionally record temperatures below zero, the highest frequency of low temperatures and the lowest temperatures being in the northern sections and the high altitudes. A few winter temperatures below −20° F. are on record. The summers are very warm, except at the higher altitudes. Temperatures in excess of 100° F. are frequent during the summer months, but the periods of such hot weather are of short duration. The growing season for most of the region is between 5 and 6 months, but it exceeds this by a month in the more favored sections and is a month shorter in less favored areas above 4000 feet.

Electrical storms accompanied by heavy rains are common during the summer months. These storms, therefore, do not contribute greatly to the fire hazard.

Owing to the diversity of the topography, the direction of the prevailing winds varies with the locality. The average wind velocity is between 3 and 7 miles per hour (Weather Bureau 1926). Maximum velocities of 40 to 50 miles per hour have been recorded on numerous occasions.

Development of Lumbering

Cutting in the southern Appalachians began after the best timber in New England and the Lake states had been cut. Cutting developed slowly at first and was confined to the more accessible areas along the streams that were used exclusively to transport the logs to the mills (Frothingham 1917, Newins 1931). The higher-quality and more accessible timber was cut rapidly by the larger operators. Even as late as 1890 only black walnut, black cherry, the finest yellow-poplar, eastern white pine, American basswood, cucumbertree, and white oak

were worth cutting. A little later the development of railroads made possible extensive cutting of many other species. The volume of timber cut increased gradually until 1909, when 4,000,000,000 board feet of lumber alone were cut (Forest Service 1928). In recent years the annual cut has been around 2,000,000,000 board feet.

Portable sawmills are playing an increasingly important part in the utilization of the small scattered tracts of timber (Frothingham 1931, Newins 1931). The average portable sawmill operator is willing to set up for a cut of 50,000 to 100,000 board feet, and in the less accessible sections they will set up for much less. New forest industries have developed in recent years to utilize smaller trees and low-value species.

The Effect of Past Practices

Cutting in the southern Appalachian region has been characterized by much culling and frequent cutting (Fig. 24), although locally some clearcutting was done to supply the demand for charcoal wood for the iron furnaces that once operated in some sections. These clearcut areas have usually restocked with a dense, even-aged sprout stand. Most of the second growth is under 50 years old now.

The first cuttings, which removed chiefly trees over 30 inches in diameter on the stump, principally yellow-poplar, white oak, black walnut, black oak, and black cherry, created small openings in which reproduction of desirable species usually became established quickly. By 1905 some species were cut to as low a diameter as 14 inches, but, since many species were not cut to so low a diameter, a reserve stand was left that could be cut profitably in 15 to 25 years. With a gradual lowering of the diameter and with more species salable, many of the old cut-over lands were cut a second and, more recently, a third, time, and some a fourth or fifth time.

Recent cutting to a diameter of 9 to 10 inches on the stump leaves a light stand, one-third to one-half of which in West Virginia is reported to be defective (Newins 1931), and the remainder chiefly species having little or no commercial value. Reproduction developing in some stands is often likely to be of low-value composition. The small amount of valuable reproduction which does become established is seriously handicapped in its growth, both by the competing reproduction of inferior species and by the large trees of the residual stand (Fig. 24).

Power skidders, still in use on the larger operations in 1931 (Frothingham 1931), contributed greatly to forest deterioration by extensive destruction of saplings and poles.

Fires, burning over much of the forest land, have killed and wounded many trees as well as destroyed the forest litter, so valuable in maintaining soil fertility on some soils (Hursh 1928).

Logging slash has never been given any attention. Where the forest is composed largely of deciduous species, neglect of slash has not been

Photograph by U. S. Forest Service.

Fig. 24. Culling has been a common practice in hardwood stands in the southern Appalachians. Large defective or otherwise undesirable trees have been left to suppress smaller trees of high-value species.

serious because the slash does not create a high fire hazard and it decomposes rapidly. In the spruce-fir types the situation is different. The enormous amount of debris—partly slash and partly shrubs that die from exposure after clearcutting—that was left from the cutting of extensive areas created a terrific fire hazard. Consequently, much of this cut-over spruce-fir land burned over within a year or two after logging, creating a large acreage of almost completely denuded land. This no longer occurs, because there is little commercial spruce left in private ownership.

On privately owned lands very little effort has been made to improve the cut-over forests by measures other than fire protection. During the CCC program, at least 500,000 acres of cut-over land in the national forests received some form of stand improvement (Buell 1943). It has been estimated that at least 5,000,000 acres need some type of stand-improvement work, chiefly cleaning. After studying twenty-eight areas 5 years after treatment, Buell reported that in general the effect on the stands was beneficial but that in many instances the sprouts from trees cut in the treatment were menacing the reserve trees so severely that a second treatment would be needed. Frothingham (1943), after studying thirty-four national timber-sale areas, reported that desirable species are more than holding their own after cutting, except for the yellow pine–hardwoods types.

THE FORESTS AND THEIR MANAGEMENT

The forests of the southern Appalachian region are extremely varied and complex in composition. Approximately 140 different species of trees, about sixty of which are commercially important, occur in various combinations to make the forests of this region the most diversified in the United States (Frothingham 1931). To simplify the discussion, the forest types are grouped into six type-groups as follows: (1) cove hardwoods, (2) oak-chestnut, (3) yellow pine–hardwoods, (4) white pine–hardwoods, (5) northern hardwoods, and (6) spruce-fir (Staff of the Appalachian Forest Experiment Station 1935), presented in the following pages in that order. In addition to these, the redcedar type should be mentioned as important on limestone soils in the Tennessee Valley and in northern Alabama.

COVE HARDWOODS TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. Ten individual forest types make up the cove hardwoods type-group (Committee Report 1932). In the aggregate they constitute possibly 10 to 15 per cent of the forest-land area of the region, each type being confined to relatively small contiguous areas in any one section. Some of the types are not restricted to the coves and moist slopes, occurring as a part of the northern hardwood forest. The following types, because of their

minor importance as cove types, are discussed only briefly: hemlock, white oak, beech–sugar maple.

The hemlock and oak types are similar to the same types of the oak region (pp. 109 and 84, respectively). The latter is more important on dry sites (p. 165). The beech–sugar maple type (see p. 183) has the characteristics of the northern hardwoods of the northeast spruce-hardwood region (p. 28). The types described in Table 7 are of major importance.

The cove hardwood forests vary in age, form, and density. Cut-over lands, mostly heavily culled, predominate. Although these culled stands vary in the volume of the residual stand and the amount of reproduction in general, the residual stand has low commercial value, either because of high defect or the low value of the species, and much of the reproduction is of inferior species, and much that is high-value species is suppressed (Frothingham 1931). In general, most of the recently cut-over lands are badly understocked. Where fire has burned over cut-over land, the proportion of the low-value species and sprouts is generally greatly increased. These cut-over and burned lands constitute the major silvicultural problem.

Even-aged second-growth stands, generally well stocked with valuable species and occupying abandoned farm land, old burns, and clear-cut lands, represent potentially the most valuable timber of the near future (Fig. 25).

Old-growth stands, either even- or uneven-aged, now occupy only a small area, which is rapidly disappearing through cutting.

Stand Regeneration and Development. *Advance Reproduction.* Although the advance reproduction in the old-growth forests was often fairly abundant [1] unless a dense shrub cover prevented, it was generally undesirable and interfered to some extent with subsequent reproduction. It may be possible to develop advance reproduction of a desirable character in second-growth stands by proper thinning in the latter part of the rotation, although there is no experimental evidence to demonstrate it.

Subsequent Reproduction. Control of reproduction so that it will be of a desirable character is an involved matter because of the great number of species composing the stands, the rather exacting site requirements of many of the better species, and the scarcity of definite knowledge about the life habits of the important species. Shrubs and

[1] The past tense is used since old-growth forests now occupy only a small area: therefore, these stands are no longer a major management problem.

TABLE 7

DESCRIPTION OF THE COVE HARDWOODS TYPES

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Black locust	Minor	Moderate	As cove hardwoods types, all of them occupy the typical coves characterized by deep, moist soils usually of loamy texture and other sites with high moisture content	Black locust	Various hardwoods and/or pines	Temporary type, succeeded by the original species of the site
Northern red oak–basswood–white ash	Secondary	High		Northern red oak American basswood	Yellow buckeye Yellow birch Black cherry Sugar maple American chestnut White ash	Semipermanent, sugar maple and hemlock gradually increasing
Yellow-poplar	Secondary	High		Yellow-poplar	Black locust Red maple Sweet birch Northern red oak Cucumbertree	Temporary type
Yellow-poplar–hemlock	Minor	High		Yellow-poplar Hemlock	American chestnut American basswood Black tupelo Northern red oak White ash Black oak White oak Sugar maple Cucumbertree	Unknown
Yellow-poplar–white oak–northern red oak	Major	High		Yellow-poplar White oak Northern red oak	American chestnut Black oak Hemlock Black tupelo Various hickories	Unknown
Beech	Minor	Low to moderate		American beech	Sugar maple Yellow-poplar Pin oak Sweetgum Red maple Northern red oak White ash Red elm American elm White oak Various hickories	Climax type
River birch–sycamore	Minor	Low		River birch American sycamore	Red maple Black willow	Unknown

vines, abundant and making luxuriant growth on many sites, offer serious competition to tree seedlings and often threaten to choke them out (Fig. 26). Each stand presents a problem in itself because of different ratios of sprouts to seedlings, advance growth to subsequent growth, good and poor holdovers, composition of trees and other

Photograph by U. S. Forest Service.

FIG. 25. Yellow-poplar, one of the most valuable species of the southern Appalachian region, has only occasionally reproduced itself well. This 56-year-old stand contains many yellow-poplar trees of excellent bole form.

plants, etc. The more significant facts about the regeneration of the more common species in these types are set forth in Table 8.

Sprouts generally constitute a large proportion of the reproduction stand after any method of cutting. However, if dogwood is cut in July or early August, sprouting is less profuse than when cut at other times (Buell 1940). This is probably true of other species also. The rapid growth of sprouts gives them an immediate advantage over seedling reproduction. Furthermore, such shrubs as mountain-laurel, rhododendron, huckleberry, alder, and hydrangea, and grapevines, present in abundance on many sites, together with the fast-growing repro-

duction of dogwood, sourwood, sassafras, and silverbell, often quickly suppress seedlings of the more valuable tree species and thus dominate the stand if competition is not controlled (Fig. 27). On the other hand, sumac is a minor competitor because it is very short-lived (Abel 1935). Response of young stands to release from competition varies with the

Photograph by U. S. Forest Service.

FIG. 26. Rhododendron, a characteristic shrub in many forest types in the southern Appalachians, when dense, seriously interferes with the establishment and development of desirable tree species. Satisfactory elimination of this shrub and of mountain-laurel is one of the important unsolved silvicultural problems.

degree of tolerance of individual species, the degree of release, vigor of trees, and crown class. In 7- to 14-year stands in Virginia and West Virginia, response to release was greatest in the most tolerant species, under the heaviest release, and among the most vigorous trees (Downs 1946). Sugar maple responded especially well to release, and even medium-vigor trees in the codominant and intermediate crown classes of this species as well as of white oak made good growth after release.

Windfall. Windfall is seldom an important factor on deep soils; but on shallow soils overlying horizontal rock outcrop, rooting is poor and windfall is a hazard. Yellow-poplar is probably more susceptible to windthrow than the other species. Windbreakage is normally asso-

TABLE 8

Requirements and Habits of Reproduction of Important Species of the Cove Hardwoods Types

Species	Sprouting Habit	Seedling Reproduction Habits and Requirements			
		Seed Production	Seed Viability	Seed Bed	Growth and Competitive Ability
Yellow-poplar	Sprouts successfully only from young trees. Sprouts are easily damaged and commonly break off stumps that decompose rapidly	Frequently and fairly abundant	Low, usually 10 per cent	Abundant moisture and light and protection from frost (McCarthy 1933)	Growth fast in open; seedlings 10–18 feet tall in 5 years. A weak competitor. Shrubs and other trees likely to choke it out. Burning the site temporarily favors the establishment, but subsequent re-establishment of heavy cover of vegetation causes heavy mortality and slow growth of surviving seedlings (Sims 1932)
American basswood	Sprouts well regardless of tree's age. Chief source of reproduction (Frothingham 1931)	Fairly good	Fairly good but fails to produce much seedling reproduction	Unknown	Sprouts grow rapidly. Moderately tolerant
American chestnut	Sprouts prolifically at any age	Not significant because of chestnut blight			Rapid growth, among the fastest

Black walnut	Sprouts successfully only from young trees. Seldom develops into good saw-log trees (Baker 1921)	Good	High	Seed must be buried; therefore germination is restricted	Moderate growth. Not a strong competitor but will push through tangles of sassafras, sumac, rose and raspberry bushes
White ash	Sprouts successfully, chiefly from young trees	Heavy crops every few years	Moderately high	Liberal supply of moisture. Light leaf litter and humus create favorable soil moisture (Sterrett 1915)	Moderate growth, 4 to 7 feet in 4 years. Moderately tolerant until pole stage
Eastern hemlock	Does not sprout	Good seed producer	Moderately high	High moisture content in first 1–2 inches of surface soil	Moderate to slow. Very tolerant; seldom killed owing to competition
Eastern white pine	Does not sprout	Frequent seed crops	High	Moderately moist	Slow growth first few years; thereafter rapid if not suppressed. Moderately tolerant
Black locust	Sprouts profusely. Suckers also	Heavy, every few years	High	Apparently a variety of types, not exacting	Rapid growth, 2 to 4 feet annually. In spite of its intolerance it competes successfully with other species in open because of rapid growth (McIntyre 1929). Heavy shrub growth may overtop it

TABLE 8 (*Continued*)

REQUIREMENTS AND HABITS OF REPRODUCTION OF IMPORTANT SPECIES OF THE COVE HARDWOODS TYPES

Species	Sprouting Habit	Seedling Reproduction Habits and Requirements			
		Seed Production	Seed Viability	Seed Bed	Growth and Competitive Ability
Black cherry	Sprouts successfully from young trees; abundant and of good form. Sprouts from mature trees; sparse and of poor form	Heavy, almost annually	High	A variety of seed-bed conditions	Seedlings make moderate growth; sprouts, rapid growth. Tolerant only during seedling stage. Later easily crowded out
Oaks	Same as in oak-chestnut type, see p. 168				
American beech	Sprouts moderately	Heavy, every few years	High	Probably best in moist humus soil	Slow growth but maintains itself under the most severe competition owing to high degree of tolerance
Sugar maple	Sprouts moderately	Heavy, almost annually	High	Probably best in moist humus soil	Slow to moderate growth. Survives in dense or open stands
Cucumbertree	Sprouts moderately	Fair	Unknown	Unknown, one of poorest reproducers	Unknown
Flowering dogwood Sourwood Sassafras Silverbell	Sprout profusely	Heavy and frequent	Probably high	Almost any type	Rapid growth in seedling and sapling stages gives them chance to dominate young stands; tolerant, but short-lived.

Photograph by U. S. Forest Service.

Fig. 27. American chestnut, silverbell, and other low-value or undesirable elements must be removed from many young stands if high-value species are to make up a large proportion of the final crop.

ciated with defective trees, but, during sleet storms, both sound and defective trees suffer.

Economic Basis

Utilization and Marketing Problems. *Relative Value of Species.* Economic utilization of existing stands in such a way that their future value will not be impaired is a complicated undertaking because of the reproductive characteristics of the various species (discussed in a preceding section, p. 144) and the wide differences in their commercial values and utility. The moist-site species, which are the predominating species of the cove types, are divided into three groups, based, as in Table 9, on their relative commercial value for the region as a whole (Staff of the Appalachian Forest Experiment Station 1935). Since commercial value is constantly undergoing change and since relative values vary in different localities, the ratings shown here are subject to change and must be modified for different localities.

Yellow-poplar, American basswood, American chestnut, maples, birches, American beech, yellow buckeye, cucumbertree, and cherry are potential pulpwood species (Frothingham 1931). If accessible to paper mills, they can often be utilized for pulpwood. The oaks have recently come into use for pulpwood in a small way. Tanning extract materials are derived from the wood of chestnut, from the bark of chestnut oak and hemlock, and, to a lesser extent, from the bark of northern red, scarlet, and white oak, and the wood of chestnut oak. Black locust is well suited for fence posts and small poles, products that make the utilization of this species in small sizes profitable (Cuno 1930). Insulator pins, another important product, must be secured from larger trees. American basswood rates highly because of the diversity of uses to which the wood can be put, producing high-quality paper by the soda process and being valuable for excelsior, posts, and box boards, as well as saw logs (Brush 1922). It has much the same utility as eastern white pine and yellow-poplar.

Of all the moist-site species, yellow-poplar has the highest general rating; it produces excellent saw and veneer logs, in addition to being useful for pulpwood and other products. On good soils white ash, black cherry, and black walnut have high commercial value. Red and white oak and eastern white pine also rank high. Hemlock is a satisfactory tree on cool sites. Of the hickories, shagbark and mockernut are the best species.

Quality Considerations. Although it is known that wood quality is controlled by various factors, including rate of growth, these rela-

tionships have been studied for only a few species in this region. The hickories and ashes must be grown in stands that are dense enough in youth to cause natural pruning and sufficiently open later to maintain a rapid growth if their wood is to have the high strength properties needed for handle or bat stock (Paul 1930, Sterrett 1917). Yellow-poplar, noted for its light, soft, easily worked wood, must not grow too rapidly if this type of wood is to be produced (Paul and Norton 1936).

TABLE 9

THE RELATIVE DESIRABILITY OF MOIST-SITE SPECIES FOR TIMBER PRODUCTION IN THE SOUTHERN APPALACHIAN REGION

Desirable Timber Species	Less Desirable Species	
	Timber Species	Minor Species—Seldom Attain Saw-Log Size †
Ashes	American beech	River birch
American basswood	Yellow buckeye	American hornbeam
Yellow birch	Butternut	Pin cherry
Black cherry	Chestnut *	Allegheny chinquapin *
Fraser fir	Kentucky coffeetree	Crabapple
Sweetgum	Elms	Flowering dogwood *
Eastern hemlock	Black tupelo *	Hawthorns
Mockernut hickory	Carolina hemlock *	American holly
Pignut hickory *	Bitternut hickory	Eastern hophornbeam
Shagbark hickory	Honeylocust	Fraser magnolia
Black locust *	Red maple *	Striped maple
Cucumbertree	Silver maple	Mountain ash
Sugar maple	Pin oak	Red mulberry
Chinquapin oak	Shingle oak	Persimmon *
Northern red oak	Water oak	Eastern redbud
White oak	American sycamore	Rhododendron
Eastern white pine *		Sassafras *
Yellow-poplar		Downy serviceberry *
Red spruce		Carolina silverbell
Black walnut		Sourwood *
		Black willow
		Umbrella magnolia

* Common also on dry sites.

† Flowering dogwood and persimmon have high value for small products but their slow growth makes them relatively low-value species (Cuno 1926).

Marginal Tree. Study of the size of the marginal tree for saw logs has been confined to two species, northern red oak and yellow-poplar, on separate operations. In these cases trees of the former species below 15 inches d.b.h. and of the latter below 17 inches had no stumpage value (Frothingham 1931). These data suggest that small trees—the actual minimum size is controlled by many factors that vary in each operation—cannot be used profitably for saw logs. They can, however, often be utilized at a profit for other products, e.g., pulpwood, mine timbers, and firewood.

Dead chestnut presents a special utilization problem in the cove types, but since this species is more important in the oak-chestnut types its utilization is discussed under that type (p. 170).

Growth and Rotation. Of significance from the economic standpoint is the fact that many of the species of high commercial value are among the fastest-growing species of the region. Eastern white pine tops the list in rate of growth (Barrett 1933, Cope 1932). White ash, American basswood, black cherry, and northern red oak are known to grow rapidly, but the last named produces a better-quality product when grown under conditions that allow only moderate growth. Several species studied in Georgia and North Carolina ranked in the following order below eastern white pine: yellow-poplar, yellow pines, scarlet oak, black oak, white oak, chestnut oak, southern red oak, and post oak.

Growth of deteriorated stands is both slow and poor in quality. Such stands improve quickly in growth and in composition after certain types of cutting. After three types of cutting—diameter limit, clearcutting, and quality selection—basal area growth per acre in 14 years was 24.0, 46.6, and 39.7 square feet, respectively, while in a similar, untreated stand growth was only 23.7 square feet (Jemison 1946). The clearcut and quality-selection-cut areas produced the greatest basal area increase in desirable species in the overstory, but in the understory these methods caused marked increases in the less desirable species because of heavy sprouting.

A rotation of 60 to 80 years should produce yellow-poplar saw logs of good quality, since McCarthy (1933) estimates that yellow-poplar trees of profitable saw-log size can be produced in 70 years in untreated yellow-poplar stands. Yellow-poplar attains pulpwood size at 20 years, but cutting for pulpwood at so early an age would be uneconomical because mean annual growth culminates after the fiftieth year (McCarthy 1933).

Financial Aspects. The facts concerning stand regeneration and development (pp. 144 to 152) demonstrate that unless money is spent for cultural operations future stands will be composed largely of low-value elements. The cost of such treatment varies with the amount of work that must be done, but it appears that costs are low enough, even in stands that require a maximum amount of work, to make the operation a profitable undertaking. Destruction of the residual stand has required 5½ to 9½ man-hours per acre on an area supporting 164 hardwoods per acre between 3 and 18 inches d.b.h., and combined liberation cutting and cleaning in more open stands has required about the same amount of work (MacKinney and Korstian 1932, Frothingham 1931, Staff of the Appalachian Forest Experiment Station 1935). CCC enrollees treated from 0.7 to 1.5 acres per day on different operations, and the most difficult areas required more than twelve times as much labor as the areas requiring the minimum amount of work. For the general run of cut-over land it is estimated that one liberation cutting and two cleanings, involving 12 to 20 man-hours per acre, should develop a stand composed largely of high-value species.

Application of Methods

Although intensive silviculture is necessary if the cove hardwoods are to yield valuable timber crops in the future, existing circumstances do not often permit it. One of the chief difficulties in the application of the best silviculture now known is the small patches of this type surrounded by extensive areas of oak-chestnut types that are less productive and often severely deteriorated. The intensity of silvicultural practice will have to be governed by economic factors, such as landownership stability, size and location of tracts of cove hardwoods, condition of the stand, etc.

Cut-over lands constitute the major problem and for that reason should probably be discussed first, but the same order is followed here as in other chapters.

For the limited area of old-growth and commercially mature second-growth stands, so located that methods which will keep the land fully productive can be used, either clearcutting or selection cutting may be employed, the choice of treatment depending to some extent on whether all the trees in the stand can be marketed profitably. Where cut-over areas cannot be kept small (because of economic limitations), seed-tree cutting has possibilities, especially when desirable advance reproduction is deficient.

Clearcutting. Clearcutting is feasible in stands in which all the trees can be marketed to advantage, if they do not contain large quantities of heavy-seeded species. This implies that either all trees are above the size of the marginal tree for saw logs or that trees below that size can be marketed advantageously for other products. Clearcut areas must, of course, be kept small enough to allow full seeding over the entire areas from adjacent stands. Where yellow-poplar or sweetgum are the major species, cutting should provide that all parts of the clearcut area are within 400 feet of uncut portions of stands that are not less than 75 feet in the narrowest dimension (Committee Report 1945). The uncut areas should be left until at least 500 well-distributed thrifty desirable seedlings per acre, 1 inch or more in diameter at ground level, are present. Seed-tree cutting can then be applied to these areas. Maximum size for clearcut areas of other light-seeded species has not been established.

Selection Cutting. Selection cutting, because it provides a better opportunity for growing each species to its most profitable size in mixed stands and because it provides a safer means of reproducing the heavier-seeded species, has definite advantages over clearcutting in mixed stands. Both uniform and group-selection cutting have a place in the silviculture of the cove hardwoods. Group cutting is advantageous if clumps of good reproduction are already on the ground; otherwise uniform cutting is generally preferable, unless possibly such intolerant species as yellow-poplar, ash, American basswood, red oak, white pine, and others are to be reproduced on areas in which case group-selection cutting is better. In any case, cutting should be heavier in stands composed chiefly of intolerant species than in those made up chiefly of tolerant species.

The interval between cuts depends on economic conditions, the character of the stand, and the rate of growth. Under the most favorable conditions the interval might be only 5 to 10 years; under unfavorable conditions, 25 to 30 years.

Seed-Tree Cutting. Seed-tree cutting appears to have some merit in stands that are deficient in desirable reproduction,[2] but for economic reasons cannot be managed intensively. The seed trees should be thrifty full-crowned trees 14 inches or larger (preferably larger) in diameter. Eight or ten trees per acre (on flat land, fewer on slopes) of heavy-seeded species like the oaks, hickories, black walnut, and

[2] The leaving of seed trees as insurance against fire is regarded as good practice even if advance reproduction is present.

cucumbertree are needed, whereas three or more per acre of light, winged-seeded species like yellow-poplar, birches, ashes, maples, and the conifers are generally adequate.

Cutting stands by any of the foregoing methods often leaves standing numerous unmerchantable trees that will interfere with the young growth. These trees should be eliminated at the appropriate time, depending on the need of the site for protection and of the reproduction for release. Trees under 4 inches d.b.h. can generally best be cut; those above this size, either girdled or poisoned.

Cleanings, discussed in detail below, are often necessary in the stands cut by any of the above methods.

Cultural Operations. The vast areas of cut-over land, which in detail are variable in the extreme, require treatments that improve their condition and growth. The treatment must be modified from acre to acre to meet the variable stand conditions. In general, it is a matter chiefly of improvement cutting and cleaning, salvaging of some paying trees, and girdling or felling of worthless wrecks. Fire protection is, of course, equally important. Obviously, in some cases an immediate cash profit is realized; in other cases the work involves an investment in a deferred income.

The first consideration should be to get rid of as many defective trees as possible together with the more salable timber so as to improve the site for the development of reproduction. Immature trees of commercial promise that occur in groups should generally be left intact. On the other hand, isolated immature trees, because they are likely to develop into wolf trees, can best be removed.

A minimum number of seed trees, as referred to under "Seed-Tree Cutting," should be reserved either to provide for regeneration if deficient or to serve as an insurance against fire. Cleaning is desirable wherever reproduction of high-value species is suffering from suppression from low-value species.

The type of treatment recommended for specific conditions is given below briefly. For a comprehensive discussion of this subject the reader is referred to Staff of the Appalachian Forest Experiment Station (1935).

Liberation Cutting and Cleaning. Most of the old-growth stands (mostly culled) can be improved by liberation cutting and/or cleaning. Often improvement cutting can be undertaken advantageously.

A widespread condition requiring improvement cutting and cleaning is found in stands in which the dominant canopy contains a high proportion of low-value species and the understory contains a poor stocking

of high-value species whose growth is impaired by severe competition from low-value species (Staff of the Appalachian Forest Experiment Station 1935). Favoring the thrifty overstory trees of high-value species by an improvement cutting and encouraging the high-value species in the understory by a cleaning in the openings constitute probably the most effective treatments.

When the overstory is of good quality, no treatment is necessary if the stand is to be harvested within 10 or 15 years; if not, an improvement cutting to remove unmerchantable overstory trees is recommended. In stands where a decadent or highly defective overstory of old growth is suppressing an understory of high-value reproduction, liberation cutting is advisable. If low-value species are competing with high-value species in the understory, a cleaning is also advisable; if not, cleaning is unnecessary.

In old-growth (and in second-growth) stands with a highly defective overstory and an understory either lacking, or made up of, low-value reproduction, replacement of the stand is advisable. Especially if the overstory contains light-seeded species, an unusual opportunity exists for real improvement. Girdling or cutting of overstory trees that are undesirable and spot cleaning in the understory are recommended. If the replacement species are light-seeded, the soil should be scarified; if they are heavy-seeded, the litter should not be disturbed. The number of seed trees left for providing for natural reproduction should be the same as for reproduction cuttings (p. 156). Replacement can be expedited by planting.

Although either girdling or poisoning rids the stand effectively of large undesirable trees, cutting should be used to dispose of American beech and black tupelo because, if girdled, they remain alive so long that they seriously interfere with the development of crop trees that were to be favored (Buell 1943).

Thinning and Improvement Cutting. Second-growth stands composed chiefly of high-value species, well enough stocked so that growth is declining, can be thinned advantageously (Fig. 28). If the material can be marketed, thinning should be so planned as to take advantage of present and future markets. Thinning technic is not well enough known for us to outline its details. Attention is called to the desirability of fairly heavy release for white ash and moderate release for yellow-poplar to produce products of the best quality (Paul 1930, Paul and Norton 1936). In the absence of a satisfactory market for small material there appears to be merit in the "crop-tree" method of thinning, whereby only those trees that interfere with crop trees are

Photograph by U. S. Forest Service.

Fig. 28. A 40-year second-growth stand of yellow-poplar that has been improved by selection thinning.

removed, the smaller ones by cutting, the larger ones by girdling. If it is feasible to repeat the operation often (at 5- or 10-year intervals), 50 to 75 trees should be freed in the first operation. If the treatment cannot be repeated so often, 75 to 125 trees should be freed, except in dense old field stands of yellow-poplar or white pine, where 150 to 250 trees should be freed (Staff of the Appalachian Forest Experiment Station 1935).

Second-growth stands in which a well-stocked overstory is composed chiefly of low-value species and of defective high-value species can be treated to advantage by improvement cutting. If there is a well-stocked understory of high-value and low-value species, a cleaning in the understory in addition to the improvement cutting in the overstory is advisable. The best specimens of both high- and low-value species should be released, the former being favored whenever possible. If the understory is well stocked but low-value species are not competing severely with high-value species, cleaning is not recommended. If the understory is well stocked but contains few high-value species, all low-value species should be removed not only from the overstory but from the understory as well. Openings in the overstory should be planted. If the understory is sparse, no cleaning is necessary; but an improvement cutting in the overstory should remove either wide-spreading low-value species, particularly those of light-seeded species (and the soil should be scarified where seed-bearing trees of high-value light-seeded species are present in the overstory) or all low-value species, and, in the absence of seed trees, it should be followed by planting.

Cleaning. Most of the young stands in the reproduction or sapling stage can be benefited by cleaning. The undesirable elements—shrubs, low-value species that are the same height or much taller than sound high-value species, and defective high-value species, usually of the same height as the sound high-value species—should be removed when they compete with sound high-value species (Staff of the Appalachian Forest Experiment Station 1935).

If there is little difference in the height of the competing elements, the cleaning can consist of releasing 50 to 150 of the best stems per acre. In treating sprout clumps the details outlined under "Disease and Insect Problems," p. 99, should be followed. Vines, shrubs, and low-value trees, except those needed as trainers or to maintain adequate stocking, should be cut. An entirely satisfactory method of eliminating rhododendron and laurel has not been developed. Sumac need not be cut (Abel 1935).

If there is a large difference in the height of the low-value and high-value species—an example is reproduction of yellow-poplar and other desirable species only 2 or 3 feet high overtopped by chestnut, silverbell, and other low-value species 10 to 25 feet high—a cleaning in the overstory is urgent. Where the suppression comes from thickets of rhododendron or laurel, release can be accomplished at the least expense by cutting only those parts of the clump that are nearest to the suppressed trees.

The number, severity, and frequency of cleanings should be gauged by the extent to which the low-value elements recover and again threaten to suppress the better species. A second and sometimes a third cleaning at intervals of 3 to 5 years may be necessary. When high-value species are abundant and are being suppressed by low-value species, the cleaning should ordinarily be heavy; otherwise a light cleaning suffices. Where young growth is sparse and seed trees are not available, planting may well be incorporated as a part of the stand's treatment.

Choice of Species. In all cutting, both reproduction and intermediate, the choice of species to be favored should be based on Table 9 (p. 153), an attempt being made to encourage a maximum quantity of sound high-value species. In the absence of an adequate number of such trees, sound low-value species should be favored over defective high-value species. Local markets should govern the choice of species.

Planting. Planting has been suggested as a means of rehabilitating poorly stocked, old, cut-over lands. Considerable study has been made of the planting problems, and the results of comprehensive investigations of the site requirements of various species and of the possibilities of direct-seeding of some of the large-seeded species have been reported (Minckler 1941*b*, 1941*c*, 1943, 1944). These reports are only suggestive of the planting technics that are most satisfactory for success, because the studies have covered only a short period of time. The reader is advised to follow future reports of these studies as a basis for more conclusive recommendations on planting.

Several points of significance appear to be sufficiently conclusive to warrant their consideration in forest planting. They are as follows:

1. Mixtures by square groups of nine or more trees seem preferable to pure stands on most sites.
2. Rodents, especially field mice, are a major factor in the mortality of all hardwood species but are especially so with sweetgum and oaks. Unless rodent

population is light or can be controlled effectively, hardwoods should be planted with discretion.

3. Black locust is successful only on soils of good fertility and good aeration.

4. The slow growth of oak seedlings originating from direct seeding indicates that planting is superior to direct seeding in reforestation of oaks, especially on sites supporting vegetation.

5. Areas supporting sassafras can be underplanted successfully with eastern white pine or yellow-poplar.

6. Aspect, soil depth, topographic position, and physical condition of soil must be considered in the choice of species.

The reader is referred to Minckler's article (1941*c*) for details of site requirements of individual species and should follow future reports on these studies for revised recommendations.

Earlier study (Korstian and MacKinney 1931) has demonstrated the futility of attempting to regenerate yellow-poplar by direct seeding. Minckler's studies corroborate an earlier study (McCarthy 1933) on the usefulness of eastern white pine and white ash in mixture with yellow-poplar but make no reference to the value of sugar maple, black locust, or red spruce in mixtures—combinations that had been recommended earlier. White pine should never be planted in pure stands (Haasis 1930).

Pines should be spaced 8 by 8 feet. Spacing of hardwoods should be 10 by 10 feet except for hardwoods that can be utilized for pulpwood, in which case closer spacing is advisable.

Slash Disposal

Although the cove hardwoods types produce large volumes of slash if cutting is heavy, the inflammability of the slash is low and its decomposition rapid because of the moistness of the site. Four- to five-year old slash has decomposed to the point where it constitutes little fire hazard. In view of these facts and the lack of evidence that slash interferes with regeneration, treatment of the slash is unnecessary. Intensive protection may be required only in cases of unusual hazard.

Disease and Insect Problems

Ecological Basis

Diseases and insects are responsible for a considerable amount of damage to the cove hardwoods. Although, to the individual trees, the chestnut blight has been the most destructive disease, its general effect

is less serious because chestnut is a minor component of these stands.

The occurrence and causes of *rot* have been studied extensively (Hepting and Hedgcock 1937, Roth and Sleeth 1939). Although many factors influence the amount of rot in hardwoods, the tree's origin (whether seedling or sprout) and the extent of wounding are the most important factors in the entrance of butt rot. The significance of butt rot in unburned sprout oak stands has been discussed previously (p. 99). Much of this applies to the species in the cove hardwoods. Top rot can be a source of considerable loss of wood in trees damaged by snow. In a study of such damage in yellow-poplar and American basswood nearly 4 years after a storm, rot had extended as far as 6 feet in the trunk (Roth 1941). Wounds under 2 inches in diameter usually heal fast enough to preclude the entrance of decay.

Nectria canker is responsible for some damage in the cove hardwoods (Hepting and Hedgcock 1937). Although several species are attacked to some extent, the canker is most detrimental to yellow-poplar and black walnut. Nectria canker is common in young stands of yellow-poplar, but dominant and codominant trees of moderate vigor or better usually recover in sufficient numbers to justify their retention as crop trees (Nelson 1940). Damage to black walnut is often severe. Dozens of cankers often occur on single trees of this species, impairing growth and rendering the wood of the tree unfit for utilization.

A virus causes *witches' broom* on black locust, resulting in an unhealthy condition of the affected trees (Grant, Stout, and Readey 1942).

The *locust borer,* an enemy of black locust, is potentially a damaging insect. The most vigorous trees and stands on the better sites, where growth is rapid, are harmed the least (Berry 1945).

Control Methods

Control of rots should be based on two primary considerations: (1) prevention of new infection and (2) reduction in the amount of existing decay. The first depends on the prevention of wounding of tree trunks (the most important considerations are fire prevention and care in logging), the retention in the stand of a maximum number of the species that are least susceptible to decay, favoring sound over wounded trees and seedlings over sprouts in stand improvement, and proper treatment of sprout clumps. In treating sprout clumps, the recommendations given on p. 99 should be followed.

Reduction in the amount of existing decay can be accomplished in cultural operations by the removal of as many infected trees as the

silvicultural condition of the stand will permit. Felled trees bearing conks, if left in the woods, should have the conks knocked off.

Trees bearing nectria cankers should generally not be selected as crop trees, although vigorous dominant or codominant yellow-poplars may be retained. If stand sanitation is practiced, all trees bearing cankers should be eliminated. If trees are not utilized, it is best to girdle them.

Control of the locust borer seems to depend on growing black locust on good sites and maintaining a stand condition that allows vigorous growth.

Control of Animal and Logging Damage

Precautions against grazing by domestic livestock are seldom necessary because the cove hardwoods have been used for grazing very little in recent years (Haasis 1926). In a single 2-year study of cattle grazing, the severe damage recorded on such valuable species as yellow-poplar and white ash emphasizes the need for exclusion of grazing unless grasses and broad-leaved shrubs are abundant (Biswell and Hoover 1945).

Much damage in logging can be avoided by means of horse logging, in place of machine skidding, close supervision of swamping to prevent excessive cutting of reproduction and saplings, and a definite effort to use trees of small promise when rough timbers are needed in any phase of the logging operation. An observational study stresses the importance of avoiding damage to the soil in logging on steep slopes. Control of water flow in skid trails is considered essential to the prevention of soil erosion (Hoover 1945).

OAK-CHESTNUT TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. The oak-chestnut type-group covers a large aggregate area and includes nine forest types (Committee Report 1932). The sites occupied by these types vary from poor to good, the poor sites being potentially low in quantity and quality production; but the good sites sometimes now support poorer stands than the poor sites because of heavy culling. The scarlet oak–black oak and the chestnut oak types, each occupying extensive areas.

TABLE 10

Description of the Oak-Chestnut Types *

Forest Type	Importance: Area	Importance: Commercial Value	Sites Occupied	Associated Species: Major	Associated Species: Minor	Place in Succession
Post oak	Secondary	Low	Dry flats, uplands, and ridges on heavy clay or loam soils, underlain by rocks or hardpan below 1500 feet	Post oak	Blackjack oak Black oak Southern red oak White oak Scarlet oak Shingle oak Various hickories Shortleaf pine Virginia pine Black tupelo	Climax type
Post oak–blackjack oak	Secondary	Low	Dry soils between 500 and 2800 feet	Post oak Blackjack oak	Shortleaf pine Black tupelo Black oak Scarlet oak White oak Shingle oak Hickories Sourwood Red maple Winged elm Allegheny chinquapin Eastern redcedar	Subclimax type
Black oak–post oak	Secondary	Low to moderate	Sandstone areas of Kentucky and Tennessee at about 2000 feet	Black oak Post oak	Scarlet oak White oak Blackjack oak Black tupelo Red maple Flowering dogwood Winged elm Southern red oak	Unknown
Southern red oak–scarlet oak	Secondary	Low to moderate	Dry sites below 1000 feet in north part of region and below 2500 feet in southern part	Southern red oak Scarlet oak Black oak Post oak Black tupelo Hickories	Shortleaf pine Virginia pine	Unknown
Chestnut	Originally major but gradually becoming minor	High	Northern exposure at 1000 to 4500 feet and southerly exposure up to 5500 feet	American chestnut Chestnut oak Northern red oak	Yellow-poplar White oak Black oak Hickories Black tupelo Sweetgum American basswood Sugar maple American beech	Temporary type

* See p. 85 for description of scarlet oak–black oak, chestnut oak, and white oak types.

are fully described in the chapter dealing with the oak region (pp. 84 and 85). The bear oak and white oak types, both of minor importance in area, are also described in the same chapter (pp. 111 and 85). The remaining types are described in Table 10.

Cut-over land, most of it heavily culled, is the dominant forest condition in the oak-chestnut types. The residual stand is commonly

Photograph by U. S. Forest Service.

FIG. 29. The stands of the oak-chestnut types occurring on ridges are often of poor quality. Cutting in these stands is often deferred until reproduction becomes established or until markets improve.

scattered, consists chiefly of low-value species, and contains a great amount of defect (Buell 1928).

Even-aged second-growth stands, occupying some of the clearcut lands, are composed chiefly of sprouts. Heart rot, which has generally entered through fire scars, has made most of these stands very defective.

Limited areas of virgin forest still remain, most of them on poor sites where timber quality is low (Fig. 29).

Stand Regeneration and Development. Although the problems in reproduction and its development vary with the individual forest type

because of variations in composition, the problems differ chiefly in degree rather than in kind. In general, it is difficult to secure reproduction of desirable composition and form unless intensive treatment is applied.

Advance Reproduction. In the few remaining mature stands, advance reproduction is generally sparse, fire often having prevented its establishment. For the type-group as a whole, chestnut oak is the most abundant species in the advance reproduction; scarlet oak is probably next.

Subsequent Reproduction. The reproduction habits and requirements of the more abundant species in the oak-chestnut types are shown in Table 11. Supplemental details on oak reproduction are given here. A 7-year study of oak seed production throws considerable light on what happens to acorns (Downs and McQuilkin 1944). Average annual acorn production per tree was approximately 1200. Destruction of, or damage to, acorns by birds, squirrels, chipmunks, and insects reduces the number available for germination to perhaps 200 to 250. Fifteen hundred to 2000 acorns per acre are needed to produce 500 to 1000 seedlings.

Effect of Competition. If conditions are favorable to the establishment of seedlings, a fairly good representation of the more desirable elements—seedlings of the higher-value species—can be expected if the stand is not treated. However, because of their rapid growth, sprouts of the more desirable species and both sprouts and seedlings of low-value species, in parts of the stand in which they are abundant, may crowd out seedlings of high-value species. Sprouts of highest origin constitute the most serious problem, because they are most likely to assume a dominant position and they are the most likely to produce a rotten tree (Roth and Hepting 1943*a*). Chestnut sprouts are especially troublesome, where they are abundant. They grow so rapidly that, even though they are short-lived (owing to destruction by the chestnut blight), they are a constant menace in seedling and young sapling stands. Except where mountain-laurel and rhododendron are dense, enough of the more desirable trees get into a dominant position to provide a moderate stocking; but, to assure the maximum of desirable components, some stand treatment usually is necessary.

Windfall. Windfall is a minor factor since many of the species are deep-rooted. Windbreakage is associated with defect in the trees and also with sleet storms.

TABLE 11

REQUIREMENTS AND HABITS OF REPRODUCTION OF IMPORTANT SPECIES OF THE OAK-CHESTNUT TYPES

Species	Sprouting Habits	Seedling Reproduction Habits and Requirements			
		Seed Production	Seed Viability	Seed Bed	Growth and Competitive Ability
Oaks	All oaks under 50 years sprout profusely and sprout reasonably well to 100 years. Chestnut oak is the most prolific sprouter (Foster and Ashe 1908, Frothingham 1931). White oak over 15 inches d.b.h. sprouts poorly (Greeley and Ashe 1911)	8 to 10 trees, 17 to 18 inches d.b.h. or 20 to 25 trees, 12 to 16 inches should yield 1500 to 2000 acorns per acre (Downs and McQuilkin 1944)	High if moisture content of acorns of white oaks does not fall below 25 to 30 per cent, or of acorns of black oaks below 20 to 30 per cent (Korstian 1927). The white oaks, because they germinate in autumn, may be seriously damaged during winter	A moist surface soil such as prevails where the soil is protected by a partial canopy or layer of leaf litter (Korstian 1927). Because oak radicals must reach mineral soil quickly, mortality is often high, large quantities of acorns falling on dry leaf litter and failing to strike root	Vary from moderate to rapid growth and from tolerant to intolerant. Growth of seedlings is in following order * (from fastest to slowest): black oak, northern red oak, scarlet oak, chestnut oak, white oak. Growth of sprouts, which is anywhere from 35 to more than 100 per cent greater, is in the following order (from fastest to slowest): chestnut oak, black oak, northern red oak, scarlet oak, white oak. White and chestnut oaks are tolerant, at least during youth, whereas the other oaks are intolerant
Hickories	Satisfactory sprouting occurs only in trees of pole size or smaller	Large seed crops are frequent nearly every other year. Seed-consuming rodents destroy large quantities of the nuts	High, if nuts do not dry out	Moderate moisture	Top growth of seedlings is moderate (about the same as chestnut oak) *; root growth is rapid (Boisen and Newlin 1910). Rapid root development aids in surviving dry weather. They are tolerant enough to survive suppression for extended periods, and respond well to release. Sprouts grow somewhat slower than those of scarlet oak

Red maple and black tupelo	Sprout profusely. Black tupelo reproduces by root suckers also	Heavy and frequent	High	Various conditions, not exacting	Seedlings grow faster than oak seedlings.* Black tupelo sprouts compare in growth with scarlet oak, red maple sprouts with chestnut oak sprouts. Moderately tolerant
Black locust	See cove hardwoods types, p. 149				
Pitch, shortleaf, Virginia, and white pine	Pitch, shortleaf, and Virginia pine sprout chiefly from trees of sapling size or smaller	Frequent and heavy	High	Mineral soil best but not exacting in requirements	Growth of white pine slow, 1.4 feet tall at 5 years.* Pitch pine somewhat faster, 2.3 feet, and Virginia pine still better, 3.5 feet in 5 years. Slow early growth obviously handicaps these species. All are relatively intolerant, shortleaf pine the least so
American chestnut Sourwood Flowering dogwood Sassafras	See cove hardwoods types, pp. 148 and 150				

* Based on data supplied by the Southeastern Forest Experiment Station, Asheville, North Carolina. The data, based on dominant stems at 5 years of age, show a range in height from 3.8 to 5.2 feet for oak seedlings, and 5.5 to 9.6 feet for sprouts.

ECONOMIC BASIS

Utilization and Marketing Problems. The dry-site species, the group to which most of the oak-chestnut types belong, are rated according to relative commercial value in Table 12.

TABLE 12

THE RELATIVE DESIRABILITY OF DRY-SITE SPECIES FOR TIMBER PRODUCTION IN THE SOUTHERN APPALACHIAN REGION

Desirable Timber Species	Less Desirable Species	
	Timber Species	Minor Species—Seldom Attain Saw-Log Size
Eastern redcedar	Black tupelo *	American chestnut
Pignut hickory *	Carolina hemlock *	Chinquapin *
Black locust *	Red maple *	Flowering dogwood *
Black oak	Post oak	Blackjack oak
Chestnut oak	Scarlet oak	Persimmon *
Pitch pine	Table-mountain pine	Sassafras *
Shortleaf pine		Downy serviceberry *
Virginia pine		Sourwood *
Eastern white pine *		

* Common also on moist sites.

The oaks have the same varied utility as in the cove hardwoods types. The pines are coming into demand more and more for pulpwood.

Dead chestnut is rapidly disappearing from the forest. Its utilization, therefore, constitutes a problem that will soon vanish with the last of the chestnut. In 1942 it was estimated that in 10 years most of the chestnut would be too badly deteriorated to be utilized economically. High costs in many of the relatively inaccessible areas and generally low volumes per acre indicate that some of the wood will never be used. Since gradual deterioration reduces its merchantability each year, time works against profitable utilization. Chestnut is used chiefly for extract wood and lumber.

Growth and Rotation. Specific growth data for individual species are not available.

Rotations of 80 to 100 years are required to produce saw timber of high quality.

Financial Aspects. Costs of timber-stand improvement are likely to be about the same as for the cove hardwoods types, but returns on these investments are likely to be less because the sites are not so productive.

A study of a mine-prop cutting in Maryland throws some light on the relative financial merit of clearcutting and partial cutting in young stands. In a 30-year even-aged stand, clearcutting yielded labor return of 114 per cent of that from selection cutting, but from two clearcuttings on a 30-year rotation profit was estimated at only 54 per cent of that under selection cutting on a 10-year cutting cycle and 60-year rotation (Hough 1945).

Application of Methods

Cutting for the present must be limited to the better stands, because only in these is it possible to apply methods of silviculture that maintain a productive stand of valuable species. Cutting of the poorer stands must await improvement of market conditions.

Partial Cutting. In stands that are not to be cut for 10 to 15 years, preliminary girdling or poisoning of wolf and other low-value trees that are interfering with the growth of valuable trees is advisable as a measure for enhancing the present crop when it is cut and for developing an understory of advance reproduction.

Cutting in mature stands should always take the form of partial cutting—selection cutting for uneven-aged stands and shelterwood cutting for even-aged stands.

Whenever possible, cutting should be so timed that the chestnut can be utilized in its most valuable form—saw logs. This means that the cutting may best be done 3 to 5 years after the chestnut dies. Since logging and transportation costs must be considered, prompt utilization is possible only if the tracts in which chestnut constitutes a large proportion of the stand are extensive in area. Otherwise the chestnut must be used for other products (see p. 170) when the reproduction cutting is applied. The amount removed in the initial cut has to vary from acre to acre with variations in stand conditions. In general, light to moderate cuttings should be attempted whenever economic conditions warrant. Trees smaller than the marginal tree should not be cut except in the interest of stand improvement. Costs and values designate marginal sizes, below which trees cannot be cut for saw logs at a profit. This marginal size depends, of course, upon ease of accessi-

bility, as well as upon species and quality. Where it is not easily determinable, it is safest to adopt the practice of cutting no trees less than 17 inches d.b.h., except as previously indicated. Smaller trees may best be left standing for continued growth. Species that will not yield good saw logs should be cut to lower diameters: black locust to 10 or 12 inches d.b.h.; scarlet oak to 12 or 14 inches d.b.h., for cross-ties; dogwood to 10 inches (Frothingham 1931). Every effort should be made to retain in the reserve stand a maximum number of the species of high to moderate value, listed in Table 12. Wherever the stand is so constituted that there is a break in diameter distribution below the merchantable trees, thus leaving few seed-bearing trees, special provision should be made to leave additional seed-bearing trees, selected from the merchantable trees. The retention of seed trees as insurance in case of fire is often advisable also. Oaks and hickories should be left at a rate of five to six trees per acre, pines at a rate of not less than one to every two acres.

The timing of the second cutting of the shelterwood method should be gauged by the condition of the reproduction.

Cultural Operations. Cultural operations must follow the reproduction cutting. Girdling or poisoning of the worthless trees in the residual stand is necessary if this has not been done in advance of, or at the time of, the reproduction cutting. Cleanings must follow later, usually 3 to 5 years after the final cutting of the shelterwood method or any of the selection cuttings. It is advisable to remove only those undesirable stems that are already in direct competition, or likely to enter into competition, with the high-value elements of the stand before the next cleaning is made. In understocked stands some low-value stems should be retained as trainers. Troublesome shrubs, sourwood, and sassafras should be cut heavily. Proper methods of treating laurel and rhododendron are not known. Flowering dogwood need not be cut unless it competes directly with high-value stems. Seedlings should always be given preference over sprouts of the same species.

Old cut-over lands are represented by stand conditions similar to those of the cove hardwoods types and should be treated in a similar manner (see p. 157).

Planting. Planting is most urgent and generally most practicable on abandoned farm lands originally occupied by the oak-chestnut types. Black locust is adapted to a variety of sites that have deteriorated. Shortleaf pine can be planted also on sites that are too poor for hardwoods. For details of planting principles the reader is referred to p. 161.

The practicability of planting on sites supporting heavy vegetation has not been determined. Because of the intense competition that planted trees meet, necessitating frequent release cuttings with the attendant high cost, the prospect does not look any too promising.

Slash Disposal

Although no type of cutting creates a heavy volume of slash on cut-over land, it constitutes a moderately high fire hazard of gradually decreasing intensity for 5 to 7 years, because the oak-chestnut sites are relatively dry (Frothingham 1931). Since slash apparently does not have unfavorable effects on reproduction and since the cut-over lands do not have sufficient value to warrant expensive methods of slash disposal, slash can be left as it falls.

Disease and Insect Problems

Ecological Basis

The *chestnut blight* through its destruction of the American chestnut has had, and will continue to have, a marked effect on the oak-chestnut forests, because 30 per cent of the timber stand of these types originally was chestnut. None of the original chestnut has escaped death by the blight. The new-growth chestnut has, at different times, been reported to be developing some resistance to the blight (Gravatt and Gill 1930, Hodson 1920), but late reports indicate that this is not true. It is ecologically significant that other species, particularly the oaks, are successfully replacing chestnut in the reproduction stand; but this succession means at least a temporary, if not a permanent, loss in growth of the stand (Korstian and Stickel 1926).

The *chestnut timber worm* frequently attacks injured or weakened parts of chestnut trees, causing "shot worm hole," a defect that depreciates the wood. Because of their weakened condition, trees so affected are easy prey for more aggressive wood borers, as well as fungi.

The *oak timber worm* is active in mature and overmature oaks of any species but particularly in white, chestnut, and northern red oak. Often unthrifty trees are killed by this insect (Frothingham 1931). The defect it causes renders the wood useless for cooperage stock.

The *Columbian timber beetle*, doing the same type of damage as the oak timber worm, attacks chiefly the white and chestnut oak. A black stain that discolors the wood is often associated with this insect.

The *hickory bark beetle* is active in weakened hickories, often killing them (Frothingham 1931). Outbreaks are rare in thrifty trees.

Two insects that damage hickory reproduction, reported from the Duke Forest, probably are present over a wider area. The *hickory twig girdler* and the *hickory spiral borer* attack and kill terminal as well as lateral shoots (Beal and Massey 1942). Fungi may do additional damage where part of the stem is killed by the insects.

The *locust borer* attacks black locust in the oak-chestnut types under the same circumstances as in the cove hardwoods types (see p. 163).

Drought increases the susceptibility of trees of low vitality, especially scarlet, black and northern red oak, to insect and disease attack. Various insects, especially the two-lined chestnut borer and certain long-horned beetles, in combination with the shoestring fungus, are responsible for the death of many trees on ridges characterized by shallow soil (Hursh and Haasis 1931). Chestnut oak is affected the least of any species.

Decay in trees of sprout origin is discussed fully on p. 163. When a sprout is removed from a group, the time required for the healing of the wound increases with the size of the wound, and thus the danger of decay is proportional to the size of the wound (Roth and Hepting 1943*b*). Healing is especially slow when the cut is not flush with the tree left standing.

The extent of top rot is dependent upon the existence of major wounds or branch stubs on the trees. Trees in the black oak group with one or more large rotten branch stubs or three or more blind knots begin to develop considerable top rot between 50 and 100 years, whereas those in the white oak group develop rot between 100 and 150 years (Hepting, Garen, and Warlick 1940).

Control Methods

With the exception of the rot-producing fungi and the locust borer, it is not so much a matter of preventing attacks by the various pests, since epidemics are uncommon, but rather a matter of prompt utilization before the wood has deteriorated to such an extent as to render it unsuitable for the more valuable products. Because of the cost of removing scattered trees, it is seldom practical to attempt utilization of trees infested with the chestnut timber worm, oak timber worm, Columbian timber beetle, and hickory bark beetle. Early reproduction cuttings in old stands with large numbers of trees highly susceptible to these pests is the most practical solution of this problem wherever economic conditions permit.

The locust borer can be controlled by the measures recommended for the cove hardwoods types (p. 164).

Since the chestnut blight cannot be controlled, the only thing that can be done is to utilize the infected trees as soon as it is economically feasible.

The butt rot hazard can be minimized by the practices outlined on p. 99.

Control of Animal and Logging Damage

Control of domestic livestock, particularly hogs, is essential to successful natural regeneration, since they are large consumers of acorns (Korstian 1927). Reduction in numbers or elimination of livestock must be a gradual process, even on publicly owned lands, because grazing rights have been established by local livestock owners through constant use of the forested lands. In this control the education of the livestock owners must play an important part. Strict regulation will certainly be necessary during the regeneration period, followed later probably by less rigid regulation. Although it appears that reduction in numbers of certain forms of wildlife may be necessary during the regeneration period, there is insufficient evidence to make such a recommendation.

Control of logging damage should follow the same plan as in the cove hardwoods types (p. 164).

YELLOW PINE–HARDWOODS TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. The yellow pine–hardwoods forests, the predominant timber stands of the Piedmont Plateau and the foothills of the southern Appalachian Mountains, are made up of eight individual forest types. Those types in which shortleaf pine and oaks predominate resemble, in the northern parts of the region, the shortleaf pine–oak forests of the oak region and, in the southern parts of the region, the shortleaf pine–oak types of the southern pine region. The shortleaf pine–white oak, shortleaf pine–post oak, shortleaf pine–southern red oak–scarlet oak, pitch pine, Virginia pine, and shortleaf pine types, described fully in the chapter on the oak region (p. 101), constitute a major part of the yellow pine–hardwoods forest. They

occupy essentially the same kind of sites and are basically of the same character as these same forest types of the oak region.

Two forest types not described elsewhere, the shortleaf pine–Virginia pine and Virginia pine–southern red oak types, occupy relatively small areas on dry south slopes (Committee Report 1932). They contain the associated species characteristic of the other types of this group.

Mixed stands of pine and hardwoods are predominantly uneven-aged. Stands dominated by pines are chiefly even-aged, especially if they originated on old fields. The hardwoods of the second-growth stands are mostly of sprout origin.

Heavy culling and fire are chiefly responsible for the poor quality of timber in the cut-over old-growth stands. Grazing by livestock, common practice in farm woodlands, has depreciated these woods still further through destruction of the tree reproduction.

The commercial value of the yellow pine–hardwood types is determined largely by the amount of shortleaf pine and better oaks, particularly white oak and red oak, that they contain.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction in mature forests is generally sparse because of past fires and grazing. Wherever fire and grazing are controlled for a few years reproduction usually becomes established promptly. In dense forests, hardwoods predominate in the reproduction, which in old field stands usually starts its invasion by the time a stand is 20 years old. By middle age a well-defined understory has developed (Billings 1938). Pine seedlings are least abundant in old stands, in dense stands, and on the poorer sites (Barrett and Downs 1943*a*). Fire favors the maintenance of shortleaf pine but has the opposite effect on loblolly pine.

Subsequent Reproduction. The abundance of pine reproduction that follows cutting depends in part on the adequacy of the seed supply. The pines are fairly generous seed producers. In a study of seed production of loblolly pine on the Duke Forest in North Carolina, two good, three medium, and three poor seed crops were produced in 8 years (Jemison and Korstian 1944). One good seed year with a production of 100,000 to 300,000 seeds per acre is sufficient to produce 1000 established seedlings; 4 medium or 10 poor seed years accomplish the same thing.

The hardwoods do not reproduce so readily, because they are not as heavy seed bearers as the pines and the burned and grazed sites do not provide a satisfactory seed bed for their establishment. Especially is this true of the oaks, the seed of which is very sensitive to

desiccation on sites that do not have a litter cover (see p. 168). The hardwoods do reproduce by sprouting from the stumps if the trees are not too old; consequently, some hardwood reproduction develops on the cut-over land immediately after cutting. Although the hardwood sprouts grow rapidly, they have little advantage over the pines in the struggle for domination of the stand because, with the exception of white oak, they are intolerant. The extent to which either the pines or the hardwoods eventually dominate the stand depends primarily on the abundance of the hardwoods, the degree to which they are growing in direct mixture with the pines, and the quality of the site. The more abundant are the hardwoods, and the more they are intermingled with the pines, the more chance they have to overtop the pines. Shortleaf pine withstands competition better than the other pines because it is more tolerant. In general, when the hardwood portion of the stand is chiefly of sprout origin, the hardwoods tend to gain a larger representation under uncontrolled competition.

Reserve stands left after partial cutting of dense old field stands do not produce satisfactory growth. In two such examples, one stand had an annual mortality that exceeded growth by 72 board feet per acre and the other produced a net growth of only 21 board feet per acre annually over a 10-year period (Chaiken 1941). Mortality was heavy among intermediate and suppressed trees and those damaged by logging. This fact emphasizes the need for systematic thinnings, in dense stands, to develop healthy trees with adequate crowns (Chapman 1941).

Windfall. Yellow pine–hardwoods stands are, on the whole, very windfirm, windfall generally being restricted to isolated trees, except in the pitch pine type, which suffers more severely in mature stands because mature trees of this species are very poorly rooted.

Economic Basis

Data on this phase of the silviculture of the yellow pine–hardwoods types are meager, specific information being limited to the relative value of species shown in Table 12, p. 170. Of the more valuable species, the pines, particularly the shortleaf pine, generally rank highest because of their superior growth and form characteristics in the yellow pine–hardwoods types. White oak and southern red oak on the better sites are of equal value.

A study of two degrees of thinning, of two forms of seed-tree cutting, and of a two-cut shelterwood system in loblolly pine demonstrated that

the cost of felling and bucking pulpwood was not significantly affected by the cutting method except under the thinning that removed approximately one-third of the pulpwood volume, in which case cost was increased 25 to 40 per cent (Downs 1942). Cost was not increased when one-half of the pulpwood volume was removed in thinning.

Application of Methods

Because of the depleted condition of most of the old-growth stands, the reproduction cutting must be a type that is economically expedient. This generally means seed-tree cutting. As important to successful reproduction as the cutting method is protection of the stand from fire and livestock. The seed trees, two to four per acre, not less than 14 inches d.b.h., should be pine, preferably shortleaf, since the hardwoods reproduce voluntarily in sufficient quantity to maintain the mixed character of the stand. Low-value hardwoods should be either cut or girdled.

Stands that are moderately well stocked with trees of a wide range in size should be cut by the selection method. A rough diameter limit of 12 to 14 inches d.b.h. can be used.

In localities where small trees can be marketed, thinning should begin in young pole stands between the twentieth and thirtieth years. If both pulpwood and fuelwood can be marketed, both pines and hardwoods can be cut; but, if only pulpwood can be sold, the poorer hardwoods should be girdled. Thinnings should be moderately heavy.

When hardwoods of sprout origin are strongly represented in a reproduction stand, a cleaning must be made within 5 years after the reproduction cutting. A single cleaning is generally sufficient. Any low-value residual trees should be disposed of at the same time.

Planting. Planting is required only on abandoned farm lands, or otherwise denuded land too far removed from seed-producing stands to guarantee prompt natural regeneration, and eroding land on which trees cannot become established naturally because of soil instability. Black locust is most effective on eroding sites, and shortleaf pine is preferable on the best and pitch or Virginia pine on the poorest of other sites. One-year seedlings of either species are recommended. If early thinning is feasible, a spacing of 6 feet by 6 feet should be used for shortleaf pine; if not, the spacing should be 8 feet by 8 feet.

Uncertainty of satisfactory seedling establishment owing to drought and relatively high cost of site preparation by hand methods make direct seeding of pines inadvisable on a large scale (McQuilkin 1946).

Slash Disposal

Pine slash is highly inflammable for 2 or 3 years and moderately inflammable for another 4 to 6 years after cutting. Since the slash volume resulting from the cutting of the average culled stand is light, the slash hazard of cut-over lands is only moderate. The isolation of individual timber tracts in the Piedmont Plateau region helps to minimize the hazard of cut-over lands in that section.

The slash is not heavy enough to have unfavorable effects on reproduction.

Slash can be left untreated except where cutting removes a heavy volume of timber over an extensive area, in which case partial piling and burning, followed by intensive protection as outlined for the yellow pine types (p. 106), should be applied.

Disease and Insect Problems

Ecological Basis

The *red ring rot*, a rot that enters through dead branch stubs containing heartwood, often causes serious damage in trees that are approaching maturity.

The *eastern gall rust* and the *southern fusiform rust* frequently attack young pines, producing distortions and swellings on the trunk and branches, and sometimes killing a part of the tree. Various oaks, particularly the black oaks and post oak, are the alternate host (Hepting 1933).

The oaks are affected by rots under the same circumstances as they are in the oak-chestnut types (see p. 174).

A new canker of pines characterized by heavy exudation of resin and no fruiting bodies has been reported in North Carolina (Hepting and Roth 1946). Its importance has not been established.

The *southern pine beetle*, which attacks any of the pines, particularly the shortleaf, can become a serious pest, although normally it does little damage. Trees weakened by fire, wind, lightning, or deficient precipitation are most susceptible to attack, and it is from such scattered infested trees that severe infestations may spread (St. George and Beal 1929). Pure pine stands are more susceptible to attack than mixed stands of pines and hardwoods (Hoffman and Anderson 1945).

Beal (1942) reports defoliation and resultant death of heavily defoliated shortleaf and loblolly pine seedlings, especially in shade,

by the *red-headed pine sawfly* in the Duke Forest. The significance of this damage has not been established.

Control Methods

Red ring rot can be controlled by a relatively short rotation and, at least in the lower part of the trunk, by early pruning.

The gall rusts cannot be controlled effectively in stands containing appreciable numbers of black oaks and post oak because of the impracticability of cutting the alternate host. In the absence of oaks, infected pines should be cut and destroyed.

Systematic removal of injured or weakened pines and the maintenance of some hardwoods in most stands, except on poor sites, reduces to a minimum losses from southern pine beetle attacks.

The cutting of any brood trees, followed by the removal and burning of the bark, usually forestalls the development of epidemics (Hopkins 1921). This work should be done between November 1 and March 1, during which time the danger of reinfestation is lowest.

If good silviculture fails to prevent heavy infestation of pine-oak stands by the southern pine beetle, special control measures must be resorted to. If logging of the stand is practical, this practice is recommended, because it provides an opportunity to utilize the trees that are cut and it effectively puts the epidemic under control. Logs should be removed from the cut-over land at once so that they may be sawed and the slabs burned (St. George and Beal 1929).

If logging is not feasible, all infested trees should be cut. Then either the bark down to where the stem is 4 inches in diameter should be removed and burned or the felled trees, lying in a north-south direction, should be limbed and exposed to full sunlight. The trees must be rolled over every few days in order that the entire bark surface may eventually be exposed to the sun.

Control of Animal and Logging Damage

Livestock must not be permitted to graze in small farm woodlands, because reproduction fails to become established when subjected to this abuse (see p. 176).

Horse skidding and high wheel roading are recommended as a system that prevents serious damage in logging (MacKinney 1934). Supervision is necessary in all phases of logging to prevent unnecessary injury

to the hardwoods because of the general disregard of hardwoods by woods crews.

Grazing in mixed stands of pine and hardwoods is not objectionable if properly regulated. It may have real value when pine is to be favored over hardwoods (Shepherd, Kaufman, and Biswell 1946).

WHITE PINE–HARDWOODS TYPES

Eastern white pine, extending to its southernmost limit in this region, occurs in three forest types—the white pine, the white pine–hemlock, and the white pine–chestnut oak–chestnut. Only the last-named type is distinctive in this region; the other two are similar to the same types of the New England white pine region (p. 45). The white pine–hardwoods forests do not occupy a large area, but potentially they have high commercial value. Oaks, yellow-poplar, and American chestnut are more prominent associates of the white pine in this region than in the New England white pine region. Plantations and second-growth natural stands make up the white pine–hardwoods forests.

Research on these types has been conducted on a very small scale. Although, in general, these forests apparently react very much like similar forests farther north and thus can be managed similarly, they differ in some details, which will be discussed briefly here. With the elimination of the American chestnut by the chestnut blight, various oaks—particularly chestnut oak, an aggressive reproducer—are becoming established in the openings. Eastern white pine reproduction responds satisfactorily to release from overstory hardwoods. In a Georgia experiment, the smaller seedlings responded to release in 2 years, and all size classes had responded in 3 years with increased growth ranging from 17 to 62 per cent (Downs 1943).

Diameter growth of pruned white pine was affected significantly during the first 5 years only when more than 26 per cent of the live whorls were removed (Barrett and Downs 1943*b*), but after 8 years differences in diameter growth were not apparent, and at that time crown ratios on pruned and unpruned trees were the same (Downs 1944). Height growth was not affected by pruning. A 20-year study of thinning in white pine plantations in North Carolina showed that crown ratio is important in rate of growth, growth being fastest in trees with large crown ratios (Frothingham 1942).

The *white pine blister rust* and *white pine weevil* are less of a threat to the white pine in the southern Appalachian region than farther

north. The scarcity of *Ribes* reduces the danger of infection by the rust, and the absence of large areas of pure white pine and the activity of the downy woodpecker and numerous other birds suppress the white pine weevil (Cope 1932). A single eradication of *Ribes*, only in those areas where they are abundant, generally protects the white pine adequately against infection by the rust. In exceptional cases re-eradication is required.

Cleanings, improvement cuttings, thinnings, and pruning can be applied similarly to these operations in the New England white pine region (p. 54). As long as chestnut continues to sprout, cleaning has to be more frequent in stands containing appreciable amounts of this species than in stands where this species is not abundant. Thinning and pruning must follow cleanings if a valuable crop is to be produced. Not in all localities can the small trees from stands under 30 years be utilized profitably, but Sechrist (1939) describes a case in which trees from 4 to 9 inches d.b.h. removed in thinning a 25- to 30-year-old plantation were utilized at a substantial profit for shingles and box boards. Pruning should be done in two or three operations, but, if circumstances require that it be accomplished in a single operation, it should be postponed until the trees to be pruned have reached a size such that pruning the first log will not remove more than 30 per cent of the living whorls (Barrett and Downs 1943*b*). Mollenhauer (1938) found handsaws best for pruning a 25-year-old white pine plantation. For high pruning, especially above 15 feet, he found the Tarzan method superior to the ladder method.

Planting can be accomplished successfully at the least expense on sites relatively free of vegetation, such as burns and abandoned farm lands. However, white pine succeeds on sites occupied by dense laurel and rhododendron, if the site is prepared by cutting strips through the vegetation equal in width to three-fourths of its height or by cutting spots whose diameters are equal to its height (Minckler 1941*a*). If laurel and rhododendron burls can be sold for smoking pipe stock, part of the cost of the operation may be liquidated. Hardwoods, especially oaks and yellow-poplar, can be used in mixture with white pine. Three-year white pine transplant stock and 1-year hardwood planting stock are recommended. Planting should be done in early spring. There is some evidence that the death of roots, which may be caused by poor root arrangement in the process of planting, provides an entrance for root and butt rot, which may increase rapidly in thinned stands through the build-up of decay organisms in the

stumps (Hepting and Downs 1944). Careful planting is, therefore, advisable.

Slash can be treated in the same way as for the yellow pine–hardwoods types (p. 179). Lopping and scattering of the slash appear advisable in thinned second-growth stands (Simmons 1935).

NORTHERN HARDWOOD TYPES

The northern hardwood types—sugar maple, yellow birch, beech–sugar maple, and sugar maple–beech–yellow birch types—are similar, except for species composition, to the sugar maple–beech–yellow birch type of the Allegheny hardwood–pine–hemlock region (pp. 125 to 126). Only the significant differences, particularly those that affect the management of these forests, will be presented.

The northern hardwood forests occupy a large area chiefly at elevations between 3000 and 4000 feet. Of the four types the sugar maple is the most widely distributed. The occurrence of Ohio buckeye, cucumbertree, and yellow buckeye and the greater abundance of oaks, particularly white and northern red oak, than in the more northern regions make the northern hardwood forests of the southern Appalachians different from those elsewhere. Stands of all types, old growth, young and old second growth, and recently cut-over lands, occur in this region.

Potentially these forests are valuable for saw-log and pulpwood production, but the best pulpwood species are not abundant enough to justify the development of pulpwood operations under present economic conditions. The relative inaccessibility of these forests makes the cost of logging high, thus mitigating against intensive silviculture.

Selection cutting in uneven-aged and shelterwood cutting in even-aged mature stands meet most successfully their silvical requirements and are likely to be most profitable financially. Cutting must generally be heavy, removing 70 to 80 per cent of the merchantable volume. The actual amount removed should be determined by local conditions, particularly the quantity of advance reproduction and economic factors. Because such heavy cutting may leave occasional large openings, the retention of a few large trees (larger than the marginal tree) is necessary where these openings are not occupied by advance reproduction. Defective, poorly formed, and insect-infested trees should be cut for stand-improvement purposes.

Unless second-growth stands are accessible to wood distillate plants or pulp mills (if near pulp mills, they should contain a considerable amount of pulpwood species), thinning is not practical now.

Such cultural operations as cleaning or liberation cutting are seldom necessary, which is fortunate because existing uses hardly justify their application.

Photograph by U. S. Forest Service.

FIG. 30. This spruce-fir land was cut and burned 1 year previously. Land of this type usually develops a dense cover of vegetation and is very slow to reproduce.

SPRUCE-FIR TYPES

The spruce-fir types, made up of three forest types and once of major areal and commercial importance at the high altitudes, have been extensively cut and replaced by other types, notably pin cherry and northern hardwoods (Korstian 1937) (Figs. 30 and 31). Most of the remaining virgin forest is within the boundaries of the Great Smoky Mountain National Park and thus is not available for cutting.

Korstian's study (1937) of the regeneration and other reactions of the spruce-fir forests demonstrated that these forests behave practically the same as similar forests in the northeast spruce-hardwood region (see pp. 7 to 28).

The chief obstacle in applying the best silviculture (selection cutting) to the remaining commercial stands is the limited area that is left, situated in relatively inaccessible sections, thus making logging and transportation costs high and the possibility of returning at an early date for a second cut rather remote.

If selection cutting is feasible, 50 to 75 per cent of the original canopy should be reserved, the amount removed to be determined by economic

Photograph by U. S. Forest Service.

FIG. 31. On the better soils hardwoods (in this case chiefly yellow and sweet birches) may completely replace the original spruce-fir forest after fire (in this case 20 years after), and there is no prospect that spruce will re-establish itself within the next generation.

conditions and the amount of advance reproduction in the stand (Korstian 1937) (Fig. 32).

Areas occupied by high-value second-growth hardwoods can best be managed during the first rotation for hardwoods (Fig. 31).

Planting provides the only means of restoring denuded or partially deforested lands (Fig. 30) to a productive condition in a reasonable time. Direct seeding has failed because of frost heaving (Minckler 1945). Recently burned areas seem to offer the best opportunity for success at the lowest cost, although sites supporting predominantly

blackberry, fern, or similar species with a density of 0.75 or less can be reforested at moderate cost because cleanings on such sites are unnecessary.

Red spruce or Fraser fir should be used only on the more moist sites, the former tree being preferable because of its superior commercial value. Red pine can be grown successfully on the drier sites, especially

Photograph by U. S. Forest Service.

FIG. 32. Mature spruce-fir forests can be reproduced successfully by partial cutting.

south slopes (Minckler 1940). Three-year transplant stock (2-1) should be used on all except the most severe sites where 2-2 stock is superior. Fall planting and an 8 foot by 8 foot spacing are recommended (Staff of the Appalachian Forest Experiment Station 1935).

Release of the planted trees in late June or early July of the first year is advised on sites with dense herbaceous and shrubby vegetation, sites with blackberry or fern cover with a density of 0.9 or more, and sites supporting young stands of undesirable hardwoods (Minckler 1945). On very rocky sites planting should be confined to soil pockets with the object of depending on natural regeneration after the planted trees reach seed-tree size.

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6 • *Southern Pine Region*

DESCRIPTION AND HISTORY

Location and Landownership

The southern pine region as recognized here includes an extensive area along the Atlantic Ocean and the Gulf of Mexico, from Maryland and Delaware to Texas and Oklahoma, dominated by the southern pines (Fig. 1). Forests in which the bottomland hardwoods predominate are included in the southern bottomland hardwood region, the most extensive area of which is in the lower Mississippi Valley. The southern pine region extends inland 100 to 250 miles along the Atlantic seaboard and 300 to 400 miles along the Gulf.

The area of commercial forest land is 164,000,000 acres (26,000,000 acres of the South is assigned to the southern bottomland hardwood region). The timberland is composed chiefly of extensive, privately owned tracts. Nevertheless, the acreage in small woodlands, especially in the northern part of the region, is rather large. In 1948 approximately 5,000,000 acres were in national forests. The area of forest land in state forests is small, approximately 500,000 acres. Public ownership of forest land is increasing on account of reversion for nonpayment of taxes.

Physiographic Features

The physiography of the region is extremely diversified. Much of the land surface is flat to gently rolling and well drained. In the foothills of the southern Appalachians and in the Ouachita Mountains the land surface is rough and hilly. The topography is also broken into little rough hills on the east side of the Mississippi River bottoms. Along the Atlantic and Gulf coasts are extensive areas of "flatwoods" —areas with very little variation in altitude, interspersed with low hillocks and ridges of sand, and mostly poorly drained. Although most of the region lies between sea level and an altitude of 600 feet,

there are fairly extensive areas in the southern extent of the southern Appalachian Mountains and in the Ouachita Mountains that rise to an altitude of 2000 to 3000 feet.

A variety of soils exists in the southern pine region. Six soil regions, each of which is characterized by a predominance of certain types of soils, constitute a large proportion of the land area: the flatwoods, the upper coastal plain, the deep sands and sand hills, the Piedmont Plateau, the Appalachian and Ozark Mountains, and the Mississippi bluffs and silt loam uplands (Bennett 1921). The black prairies of Alabama and Mississippi are of local occurrence.

The flatwoods region extends 50 to 100 miles inland along the Atlantic and Gulf coastal plain. It is characterized by a flat topography and poor drainage, water standing on the surface for considerable periods after heavy rains. Depressions, locally called "ponds," are usually covered with water the year round, except during short periods of extremely dry weather. The flatwood's soils either have a stiff clay subsoil or a sandy hardpan.

The upper coastal plain lies inland from the flatwoods and the regions of deep sands and sand hills. The topography is slightly rolling, and the soils have good drainage. The predominant soils are grayish to light brownish in color with deep, red, friable subsoils.

The deep sands and sand hills are important chiefly in central Florida, although they occur also in southern Georgia and Alabama. The land surface of this soil region is gently rolling to hilly. The sands are deep, and they are gray to light brown in color. "Hammock" lands with clay subsoils overlying limestone are interspersed through this soil region.

The Piedmont Plateau occupies a broad elevated belt some 100 to 150 miles inland from the Atlantic seaboard. It extends into the foothills of the Appalachian Mountains. The topography is rolling to hilly. The predominant soils have a clay to sandy loam surface soil and a brittle or only moderately friable, gritty to plastic, clay subsoil.

The Appalachian and Ozark Mountain region is a series of low mountains. Over most of the area the soils are deep. Locally, rock outcrops and stony cliffs are common. The soils are chiefly sandy loams, silt loams, and clay loams.

The Mississippi bluffs and silt loam uplands region occupies a belt east of the Mississippi River bottoms. The topography varies from gently rolling and undulating to severely dissected or rough and hilly. The predominant soils have a silt loam surface soil, underlain with clay, with silt loam at greater depths.

The black prairies are localized in central Alabama and northeastern Mississippi. Their topography is undulating to gently rolling, and the drainage is good. The soils are mostly dark-colored clays and loams. The subsoil contains considerable limy material.

Most of the soils, except in swamps, are low in humus content. Owing to the frequency of fires (Heyward and Barnette 1934), vegetation is not luxuriant. However, where fires have been under control for several years and where prescribed burning has not been practiced, grass and shrubs are rank and needle accumulation is heavy. Erosion is serious on certain silt loams where the vegetative cover has been largely destroyed.

Streams are probably more numerous per unit of area in this region than in any other section of the United States. The many small tributaries feeding into the larger streams form a dense network. The main rivers are bordered by alluvial flat land from 1 to 3 miles in width. These alluvial lands support hardwood timber, except where cleared for agriculture.

Climatic Features

Heavy precipitation, a humid atmosphere, mild temperatures, and a long growing season are outstanding characteristics of the climate. There is considerable regional variation in the various climatic elements because of differences in latitude, longitude, and the relation of land to the Atlantic Ocean and Gulf of Mexico.

The average annual precipitation over most of the region is between 45 and 55 inches, but several points record more than 60 inches and some stations in Arkansas, Texas, and Oklahoma record less than 40 inches (Weather Bureau 1926). Precipitation is heaviest along the coast, gradually diminishing inland and to the west. There is no distinct dry season; however, rain is less copious during October and November than at other times. During this "dry" season mean precipitation is approximately 3 inches a month. The heaviest precipitation occurs from December through March, with a secondary maximum from June to mid-August, except in parts of Florida, where the wettest period is from July to September, and north from Virginia, where it is from April to September. Snowfall is light, many stations never having recorded any. The northern edge of the region has a mean annual snowfall of 5 to 12 inches (Weather Bureau 1926).

The atmosphere is generally humid, relative humidity of 80 to 90 per cent being frequent. During the drier seasons the relative humidity frequently falls to 25 or 30 per cent in some sections.

Very low temperatures are exceptional, although they do occur, as, for example, when a temperature of −2° F. was reported at Tallahassee, Florida, in February 1899. The mean annual temperature ranges from 51° F. in some of the northern points to 68° F. in some of the southern states. January, the coldest month, has a mean temperature of 33° to 54° F.; July, the hottest month, has a mean temperature of 72° to 83° F. The hot weather from May to September is broken by short cool spells that follow electrical storms.

The growing season is long, varying from less than 6 months in the extreme north to more than 9 months in the more southern parts. The greater portion of the region has a growing season of 7 to 8 months.

Electrical storms are most common during the summer months, but they may occur at any time of the year. Except in northern Florida, they are usually accompanied by ample rainfall and, therefore, are generally not a source of fire hazard.

Parts of the region are subjected to tropical hurricanes. During these storms, wind velocities of more than 100 miles per hour are attained.

Tornadoes may occur anywhere in the region, but they are more frequent in the interior parts of the region. Numerous stations at other times record maximum wind velocities of 40 to 75 miles per hour (Weather Bureau 1926). The average wind velocity is ordinarily below 10 miles per hour. Winds are usually from a southerly direction.

Development of Lumbering

Extensive lumbering in this region began about 1880, when the completion of the railroads gave the South a satisfactory outlet for lumber to the North. There was a steady and rapid expansion in the lumber industry from 1880 to 1900, particularly during the last 10 years of the period. In 1889 the production of lumber was nearly 4,000,000,000 board feet. By 1904 it had reached nearly 10,500,000,000 board feet annually, and in 1909 it attained its peak of over 16,000,000,000 (Forest Service 1927). More recently the lumber cut has been around 11,000,000,000 to 12,000,000,000 board feet annually. Large sawmills have been replaced to a considerable extent by small portable sawmills, which number several thousand. Cutting of timber for pulpwood has been increasing in volume since 1930 and now constitutes more than 10 per cent of the timber cut.

The Effect of Past Practices

With the exception of the limited area of forest in public ownership (only those few areas that were acquired at an early date) and scattered areas of private forest, timbered lands in the southern pine region have been badly abused.

Cutting for saw logs on privately owned lands has, for many years, removed trees to low diameters. Since 1935 cutting has been more conservative on many of the lands in ownerships of 5000 acres or more. The expanding market for pulpwood, which enables the utilization of trees 4 to 5 inches d.b.h., has made the removal of timber even more complete on lands whose owners had no plan for managing their lands. Although close cutting usually does not result in deforestation, it is the cause of forest deterioration. Close cutting for saw logs only is less damaging in uneven-aged than in even-aged stands, because of the prevalence of small young trees in the former. However, where pulpwood is cut, utilization is often so close that cut-over land is left sparsely stocked. Where hardwoods grow in mixture with the pine, a partial stand is always left after cutting, because the hardwoods generally are not utilized to low diameters.

The power skidders, very destructive to young growth, have caused serious deterioration in longleaf pine stands, where they were once used extensively. Skidders have given way to other types of logging which are less damaging.

Destructive turpentining has been the cause of much forest deterioration in the eastern part of the region, particularly in second-growth stands in Georgia and Florida. In the western part of the region, where turpentining is secondary to lumbering and the trees are operated for turpentine for only 2 or 3 years on a lease basis, conservative methods have minimized the damage from turpentining. Turpentining has generally been very destructive. Gutters driven deeply into the trees, deep chipping, and the running together of faces—common practices—lower the vitality of the trees and weaken them mechanically, thus making them easy prey for insects, fungi, and wind (Forbes 1930). Fires have done severe damage in turpentined stands that have been abandoned. The market for pulpwood has largely done away with the former practice of abandoning such stands.

Wildfire has been a large factor in forest deterioration by reducing stocking, increasing the proportion of such inferior species as turkey,

blackjack, and bluejack oak, causing extensive rot, particularly in hardwoods, and materially reducing the growth of pine saplings. Recurring wildfires accentuate these conditions. However, the pines have sufficient resistance to fire to prevent their complete elimination even when wildfires are frequent.

In the early thirties it became evident that the attempt at complete exclusion of fires in the pine forests as practiced by public forestry agencies was not solving the fire problem, and, at least in the longleaf pine type, it was a deterrent to regeneration. With the accumulation of vast quantities of inflammable material which followed several more years of fire exclusion on lands protected by public agencies, damaging accidental fires became more frequent. It grew abundantly evident that some means must be devised to reduce the fire hazard at least on longleaf pine and possibly slash pine sites where the ground cover was especially profuse. This need led to the initiation around 1940 of a burning practice first known as controlled burning but more recently referred to as prescribed burning (Chapman 1947*b*). Prescribed burning, applied usually every 3 or more years on a given area, is being adopted widely on longleaf pine lands and to some extent on slash pine lands to reduce the fire hazard, control the brown spot needle blight on longleaf pine, improve grazing, reduce undesirable tree species, and prepare the site for regeneration (Lemon 1946, Squires 1947).

Seedling damage by hogs has also been a potent factor in forest deterioration in the longleaf pine type.

In 1945 Wakeley estimated that 12,843,600 acres of forest land were in need of planting. The restoration of idle land to production through planting had covered 870,000 acres up to 1940, mostly since 1919, and 730,000 acres of this amount was considered successful. Since the termination of World War II there has been increased activity in planting, and it now appears that an extensive forest planting program will materialize on privately owned lands.

In contrast to this general run-down condition of most cut-over lands, some national forests (only those that have been under Forest Service administration for a long period) and some privately owned cut-over lands are very productive (Fig. 40). One operator reported in 1931 that, because of conservative cutting, fire control, and the elimination of hogs from the longleaf pine, he had more timber then than he had had in 1905 when he started practicing forestry (Hardtner 1932). In 1946 the proportion of privately owned land under some form of management was approaching 20 per cent of the total.

THE FORESTS AND THEIR MANAGEMENT

Many different forest types are represented in the southern pine region, but discussion will be limited to the four major type-groups, because either little is known about the others or they are more important elsewhere and, therefore, discussed fully in other chapters. The four principal southern pines, longleaf, shortleaf, loblolly, and slash, are the most prominent species in three of the type-groups, whereas another conifer, Atlantic white-cedar, is the most important species of the fourth type.

The southern pine region is traversed by many streams and rivers, along which are forests of hardwoods and baldcypress similar to those of the southern bottomland hardwood region. These forests are represented by the following types: pondcypress, baldcypress, live oak–cabbage palmetto, water oak–willow oak, sweetgum–yellow-poplar, and water tupelo. Other types, not described in detail, are the sand pine type, characteristic, particularly, of the very dry sands of Florida, and extending into Alabama, and the pond pine type of the Atlantic coastal plain found on the flatwoods and other areas of poor drainage. Both of these occupy a large acreage but have little commercial value.

The most important forests of the region are those that include the longleaf pine, slash pine, and loblolly pine–shortleaf pine type-groups and the Atlantic white-cedar type. Because of the high commercial value of the four principal pines, forests containing these species have been logged extensively. Between 1933 and 1946 the area of virgin forest dwindled from 8,500,000 acres to less than 1,000,000 acres. Nearly half of the forest-land area is in stands of saw-timber size. More than 80,000,000 acres consist of young second growth under sawlog size in various stages of development and stocking. Logging and fires have changed radically the character of the forest over a vast area.

LONGLEAF PINE TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. Three forest types are represented in this group, the longleaf pine, longleaf pine–turkey oak, and longleaf pine–slash pine. The last named, because it is more closely related silviculturally to the slash pine types, is discussed as a part of

the latter group. Table 13 gives essential information on the longleaf pine and longleaf pine–turkey oak types.

Owing to its natural advantages in regeneration, loblolly pine has replaced longleaf pine on millions of acres of land, thus reducing the area originally occupied by the longleaf pine types.

TABLE 13

DESCRIPTION OF THE LONGLEAF PINE AND LONGLEAF PINE–TURKEY OAK TYPES

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Longleaf pine	Major	High	Dry sandy and sandy-clay soils	Longleaf pine (often nearly pure)	On the dry sites as an understory: Turkey oak Bluejack oak Post oak On moist sites: Live oak Sweetgum Southern red oak Loblolly pine	Climax type on sandy soils and sandy clay hills of the upper coastal plain; temporary or subclimax type on semipoorly drained sites of flatwoods (Committee Report 1932)
Longleaf pine–turkey oak	Secondary	Low	Dry soils	Turkey oak Longleaf pine	Various oaks	Temporary type following cutting and fires. Replaced by longleaf pine and ultimately by oak-hickory forest (Pessin 1933)

Even-aged stands are characteristic of both virgin and many second-growth longleaf pine forests (Fig. 33). Second-growth stands that originated in old fields are generally overstocked; those that originated on cut-over lands are irregularly stocked and may be uneven-aged by groups as a result of irregular establishment of reproduction due to localized unfavorable seed-bed conditions. They vary in stage of development from sapling to saw timber.

Cut-over lands that are not well stocked with second growth are variable in character. Stands with a sparse overstory and sparse understory predominate. Over limited areas there are stands with a

sparse overstory and a dense understory of both low-value and high-value species (Staff of Southern Forest Experiment Station 1933). The overstory generally consists chiefly of defective pines and inferior hardwoods.

The most common type of longleaf pine–turkey oak stand is an open-grown, irregularly stocked stand of oak saplings and poles inter-

Photograph by Southern Kraft Division of International Paper Company.

FIG. 33. A well-stocked 35-year-old stand of longleaf pine from which 5 cords per acre of pulpwood was recently cut.

spersed with a few longleaf pines of the same or larger size. On some sites longleaf pine has given way almost entirely to turkey oak.

Stand Regeneration and Development. *Advance Reproduction.* Longleaf pine is conspicuously absent in the reproduction of uncut stands, except occasionally in large openings. Stands that have been repeatedly burned support little or no reproduction of any kind, whereas stands protected from fire for several years generally develop a reproduction stand of other species. Wherever slash or loblolly pine occur in, or adjacent to, longleaf pine stands, these species become established under fire protection. If hardwoods are near by, reproduction of these species soon establishes itself under fire protection

(Heyward 1939). Subsequent reproduction must, therefore, be the basis for new stands of longleaf pine.

Subsequent Reproduction—Seed Requirements. Since the associates of longleaf pine reproduce readily and most of them are low-value species, successful management of the longleaf pine types depends upon the creation of an environment favorable to the establishment and growth of longleaf pine seedlings. Therefore, major emphasis will be placed on the factors that influence the reproduction of longleaf pine.

Longleaf pine is not a prolific seed bearer. There was some indication that large seed crops were borne at intervals of 4 and 7 years in cut-over and virgin stands, respectively, and that variations in the seed production of individual trees were influenced by thrift and crown size of the tree (Chapman 1926), but recent studies indicate that seed production is very irregular, climatic conditions probably being the controlling factor.[1] This relatively infrequent seed production, together with the slow early height growth of the seedlings,[2] is likely to be a handicap to longleaf pine, when other species grow in mixture with it.

Approximately four trees per acre between 13 and 16 inches d.b.h. and of average or less than average height, on a very favorable site, and six to eight such trees per acre on a poor site should produce enough seed during a good seed year to provide a well-stocked stand of reproduction (Fig. 35). A 16-inch d.b.h. tree is the most efficient seed producer, whereas trees 10 to 11 inches d.b.h. are the least valuable in this respect (Chapman 1926).[3] Because longleaf pine seed is large and relatively heavy, its dissemination in sufficient quantity to provide an adequate stocking of reproduction is limited to a distance equal to two or three times the height of the seed tree.

Subsequent Reproduction—Establishment. A great many independent studies and observations at widely scattered points over a

[1] Numerous statements in this chapter not substantiated by references are based on research workers' correspondence with the author or the *Occasional Papers* of the Southern Forest Experiment Station at New Orleans, Louisiana. The *Occasional Papers* are based on limited research on particular problems; therefore, the conclusions contained in them are subject to subsequent change. *Occasional Papers* 33, 57, 58, 60, 64, and 71 are particularly valuable for a discussion of certain silvicultural problems.

[2] Although the top of a longleaf pine seedling makes no growth in height for 3 to 7 years, the root penetrates the soil deeply, thereby giving the seedling a firm foothold.

[3] Although the foregoing data are based on a single study in Louisiana, the results are probably reasonably applicable to much of the longleaf pine type.

period of 35 years lead to the following conclusions regarding longleaf pine regeneration:

1. Germination of the seed on a site barren of needle litter and/or vegetation is much superior to that on a site covered with needle litter or supporting vegetation, particularly grasses (Buttrick 1914, Cary 1932, Chapman 1936, Demmon 1935, Osborne and Harper 1937, Roberts 1936, Wyman 1922). The deeper the pine-needle litter, the poorer the germination. Seed beds prepared by prescribed burning, disturbance of the soil (by disking or plowing), and grazing produced two to twenty-five times as many seedlings as untreated seed beds (Chapman 1936, Osborne and Harper 1937). However, an investigation in Mississippi revealed that, where birds and rodents are abundant, regeneration may be seriously retarded by heavy seed losses on freshly burned areas (Gemmer, Maki, and Chapman 1940). This retardation did not occur on less recently burned areas, because the grasses and light needle cover afforded protection to the seeds. First-year survival on prepared sites—particularly when prepared just before seed fall—is also superior to that on unprepared sites.

2. Ultimate survival of longleaf pine seedlings is influenced by the amount of competition they encounter with grass, herbs, shrubs, reproduction of other tree species, and seed trees, as well as their ability to make normal growth during the early critical years (Chapman 1926, 1932). Chapman (1941) has concluded from a study of a virgin stand of longleaf pine that seedlings of this species will not survive within 30 feet of a large longleaf pine.

3. Fire plays an important role in the survival and growth of longleaf pine seedlings. During the cotyledon stage, the lightest fire kills a seedling. Seedlings between 6 inches and 4 feet tall are moderately susceptible to fire damage (Chapman 1947*a*, Wakeley and Muntz 1947). Therefore, uncontrolled fires can be very damaging or even disastrous to longleaf pine seedlings. New longleaf pine reproduction is not likely to become established for several years, but hardwoods, if present, soon become re-established by sprouts from the original trees. Where slash or loblolly pine are present, seedlings of these species are killed by uncontrolled fire, but they may soon become re-established because they bear seed rather frequently. Established longleaf pine seedlings suffer a reduction in height growth on sites that are burned annually, but most of them survive the fires. (Bruce 1947; Demmon 1935; Wahlenberg 1937; Wahlenberg, Greene, and Reed 1939.) A small longleaf pine seedling develops a thick corky bark that protects the cambium and a dense mass of upright needles that protects the terminal bud from the heat of a fire. These unusual characteristics make young seedlings relatively fire-resistant.

Prescribed burning can have entirely different effects on longleaf pine regeneration, chiefly beneficial, by reducing seedling infection by the brown-spot needle blight and in some cases possibly reducing temporarily competition from other vegetation (Chapman 1926, 1947*a*; Siggers 1932, 1934; Wakeley and Muntz 1947). Small seedlings whose foliage is not over 18 inches

above the ground are frequently infected by the brown-spot needle blight, which, when it is so serious as to cause complete defoliation of a seedling for several seasons, weakens it severely, often causing death. A prescribed fire over an area of not less than 10 acres, by consuming the infected foliage, reduces greatly the infection by this blight for 1 year, with less reduction for the second and third years. Since infection by the blight causes reduced growth,

Photograph by U. S. Forest Service.

FIG. 34. When longleaf pine seedlings are attacked by the brown-spot needle blight, their growth is so impaired that they are easily suppressed by grass or other vegetation.

prescribed fire, by reducing infection, indirectly stimulates growth, often doubling it (Fig. 34).

4. Especially on sites with a heavy grass cover, establishment of longleaf pine seedlings is aided by moderate cattle grazing after the first year, because vegetative competition is reduced thereby (Chapman 1926).

5. Longleaf pine seedlings cannot become established where hogs, either wild or domesticated, have access to them, because the animals, unless they are fed at home, can quickly destroy the entire seedling crop (Bruce 1947). Hogs are especially fond of seedlings from 4 to 8 years old.

6. The hardwood reproduction is chiefly sprouts regardless of the type of treatment applied to the site, although seedling reproduction increases if fires do not occur.

Subsequent Reproduction—Ultimate Composition. The ultimate composition of a stand resulting from subsequent reproduction depends

first on the initial survival of the various species (which is determined by the factors discussed in the foregoing paragraph) and second on subsequent conditions of the site, that is, the abundance of competing vegetation naturally present and the extent to which the hardwood reproduction and other vegetation are controlled where it is abundant. Since the hardwoods sprout during the first growing season after a fire kills them and since the sprouts grow rapidly, they soon overtop the pines, especially the longleaf. The longleaf pine being particularly intolerant suffers serious loss in height growth when suppressed, and if suppression continues for several years many of the pine seedlings succumb. Pessin (1938, 1939*b*, 1944) has found that seedlings growing at high densities or in competition with grass or scrub oaks make very slow height growth. He has demonstrated that growth of longleaf pine seedlings is greatly accelerated by release from competing vegetation. In one instance growth was increased by eleven times. Pessin (1939*a*) believes that, when longleaf pine seedlings are not released from competing vegetation, height growth does not begin until the horizontal roots of the pine seedlings are developed at depths lower than the roots of the competing vegetation. If the hardwoods are kept under control for the first 15 years, the pine has such an advantage that hardwoods are forced into the understory where many of them eventually die, with the result that longleaf pine dominates the stand. On the other hand, if the hardwood reproduction and other vegetation are not controlled, longleaf pine is likely to be only sparsely represented in the final stand.

Windfall. Outside the hurricane belt longleaf pine stands suffer from severe windfall damage chiefly on soils underlain by hardpan, which the normally tap-rooted longleaf pine cannot penetrate. In the hurricane zone nearly all trees are uprooted in severe wind storms, but generally enough trees are left standing to provide a source of seed for future regeneration, which, if the surviving trees are young, may be delayed for a decade or two.

Turpentined trees are more or less susceptible to windbreakage, the degree of susceptibility depending largely on the depth of chipping and tin setting and the extent to which insects have invaded the tree trunks, thus causing mechanical weakening of the trunk.

Economic Basis

Utilization and Marketing Problems. *Relative Value of Species.* In Table 14 the species of the longleaf pine and slash pine types are arranged by their relative value for commercial wood products.

TABLE 14

THE RELATIVE VALUE FOR COMMERCIAL WOOD PRODUCTS OF THE SPECIES OF THE LONGLEAF AND SLASH PINE TYPES

Commercially Valuable Species	Species of Little Commercial Value: Never Attain Saw-Log Size	Species of Little Commercial Value: Attain Saw-Log Size
Longleaf and Slash Pine Types (exclusive of longleaf pine–turkey oak type)		
Longleaf pine	Flowering dogwood *	Post oak
Slash pine	Red maple	Southern red oak
Loblolly pine	Blackjack oak	Pond pine
Pondcypress	Bluejack oak	Sand pine
Swamp tupelo	Live oak	
Longleaf Pine–Turkey Oak Type		
Longleaf pine	Flowering dogwood	Southern red oak
	Black tupelo	Sand pine
	Hawthorn	
	Mockernut hickory	
	Pignut hickory	
	Blackjack oak	
	Bluejack oak	
	Live oak	
	Post oak	
	Turkey oak	
	Persimmon *	

* Although not attaining saw-log size, dogwood and persimmon are valuable in small size for special products.

The pines, because of their varied utility, being valuable for lumber, cross-ties, poles, piling, and pulpwood, are the most valuable trees. Longleaf and slash pine, because of their utility for naval-stores products, offer an even greater opportunity for diversified utilization. Pulpwood utilization, discussed in detail under the loblolly pine–shortleaf pine types (p. 224), provides an excellent market for small materials.

The recent rapid expansion in the pulp and paper industry, with the attendant expanded market for pulpwood, raises a vital question regarding the relative value of the timber for lumber, poles and piling, and pulpwood. More labor and capital turnover are required to convert pulpwood into paper than to convert the same volume of saw logs into lumber. The landowner, on the other hand, gets a greater income from a given quantity of wood marketed as saw logs, poles, or piling than when marketed as pulpwood. It appears that the economic welfare of the region is served best by making the production of pulpwood the secondary, and the production of saw logs the primary, objective of forest management (Behre 1936). For utilization as lumber the longleaf pine and slash pine (which is sold on the lumber market as longleaf pine) command the highest price of the pines.

Studies of the marginal tree for lumber production and for pulpwood production have dealt chiefly with loblolly and shortleaf pine (discussed on p. 223). It is probably safe to assume that the general principles applying to those species apply reasonably well to longleaf and slash pine. In this case it is usually unprofitable to cut trees under 12 inches d.b.h. for saw logs and, in special cases, under 15 to 16 inches. Pulpwood trees under 6 inches d.b.h. leave little or no margin for profit and stumpage.

Since the production of naval-stores products—turpentine and rosin—does not destroy the tree (they are derived from the oleoresin as a by-product of the tree), the tree can serve a dual purpose if proper management is applied. Conservative turpentining methods not only maintain the vitality and rate of growth of the tree and cause a minimum amount of deterioration of the wood but also result in the best yields of oleoresin, which means larger financial returns (see p. 207) (Gerry 1922, 1923, 1931*a;* Wyman 1932).

Growth and Rotation. Longleaf pine is the slowest growing of the commercially valuable pines found in the longleaf pine types. The average annual growth in board feet (International rule ¼ inch) for fully stocked stands at the culmination of growth (80 years) is 379, 679, and 507, respectively, for longleaf, loblolly, and slash pine (Forbes and Bruce 1930). The rotation for saw logs is 80 years. Eldredge (1931) suggests a rotation of 40 to 60 years for naval-stores production, the turpentining to begin when the trees attain a diameter of 10 inches d.b.h. On the best sites this size is attained in about 20 years; on the poorer sites, in about 25 to 30 years.

Growth of both young and old trees can be increased by providing additional space for trees previously crowded. Young trees respond best to heavy low or crown thinning (Barrett and Righter 1929). Trees in thinned stands yield more oleoresin than trees in unthinned stands because of their more rapid growth and their longer crowns (Akerman 1928).

Pruning influences growth of small trees when it removes a large proportion of the live crown. When open-grown longleaf pines were pruned in one operation to a height that would yield one clean 16-foot log, trees 24 feet tall suffered marked reduction in diameter growth, trees 34 feet tall suffered slight growth reduction, but trees 42 feet tall were unaffected (Bull 1943).

Barrett (1929) and Chapman and Bulchis (1940) report accelerated growth of longleaf pines, 8 to 12 inches d.b.h. at the time of cutting, that were completely released by cutting. Barrett found diameter growth of 4.8 to 5.8 inches in 20 years, and Chapman and Bulchis found 8.5 inches in 31 years. The best growth was reported on trees with crowns 40 feet or more in length. The fastest of these rates of growth (less than four rings per inch) are those which Koehler (1938) finds in slash and loblolly pine, causing the production of wood low in density, low in strength for its weight, and shrinking excessively longitudinally—wood that is inferior for lumber. This type of wood gives a lower yield of pulp per cord than slower-growth wood, although the quality of pulp is satisfactory.

Financial Aspects. Money invested in silviculture pays quick returns because of the quick response, and it can be made reasonably safe by small expenditures for fire protection and periodic prescribed burning. On the basis of extensive application, the cost of prescribed burning has averaged about 10 to 15 cents per acre, and the damage to the forest has been about the same (Squires 1947). Spread over the 3-year period for which it is designed to give effective protection, the total cost is 7 to 10 cents per acre annually. The burn applied for regeneration purposes could logically be charged to the cost of reproduction.

Cost of Reproduction. Chapman's studies (1926) demonstrate that mature longleaf pine stands can be reproduced naturally at a low cost. On a per acre investment of $5.00 in seed trees and $3.00 in land and an allowance of $0.10 per acre per year for taxes, the growth on longleaf pine seed trees returns a 3 per cent dividend.

Planting is a more costly method of securing reproduction than cutting methods that provide for natural regeneration. On denuded areas

planting is the most economical and practical method of securing a new stand.

Cultural Operations for Saw-Log and Pulpwood Production. It was pointed out earlier (p. 203) that the production of a valuable stand, i.e., one containing a large proportion of longleaf pine, is dependent on the suppression of the hardwood element and other vegetation. The economic implications are therefore obvious. The relative merits, particularly from the financial standpoint, of prescribed burning and cleanings have not been determined. One advantage of the former practice may be the reduction in fire hazard that it accomplishes—an advantage that may weigh heavily financially (Eldredge 1935, Simerly 1936) if loss of growth does not offset it (MacKinney 1933). The destruction of "wolf trees" appears equally important to the maintenance of normal growth of longleaf pine.

Pruning in understocked stands and thinning in fully stocked stands should be profitable practices. Pruning is advantageous only where saw-log production is the objective, whereas thinning has application in stands managed for any type of product. Limited study of the longleaf pine types indicates that under average conditions one hundred 5-inch longleaf pines can be pruned to a height of 17 feet in approximately 6 man-hours, a practice that increases greatly the amount of the better grades of lumber products (Bull 1937).

Influence of Naval-Stores Practices on Financial Returns. The yield of gum, length of operation, and, in turn, the profit from naval-stores operation are intimately related to operating methods. Type and size of tree are of primary importance. Trees under 9 inches d.b.h. yield so little gum that only when naval-stores prices are unusually high or when the trees are of exceptional thrift can a profit be realized on their operation (Wyman 1922). Fogelberg (1942) shows that profit from slash pine used for naval stores increases when trees are not worked until they are 11 or 12 inches d.b.h. Maintenance of vigor and rapid growth is dependent in part on proper spacing of the trees at all times. This implies that dense, young sapling stands must be thinned before the material to be removed is salable. By the chosen-tree method Akerman was able to thin such stands for $1.53 per acre, and by low thinning for $3.07 per acre, either of which should be a low enough investment to yield a profit in quicker and larger yields of oleoresin (Akerman 1929).

The technic of working the trees for turpentine has a profound effect on yield of oleoresin as well as on the length of time that trees can be operated—both of which greatly influence financial income.

Comprehensive studies demonstrate that low (0.32 inch high), shallow (0.5 inch deep for slash pine, 0.75 inch deep for longleaf pine) streaks on narrow faces (covering not over one-third of the tree's circumference) increase the gum yield 25 to 50 per cent over the yield obtained from high, deep streaks on wide faces and, in addition, cause the minimum mechanical weakening of the tree, conserve the vitality and growth of the tree, and increase the length of the working period (Gerry 1922, 1923, 1925, 1931; Wyman 1932). In one study (Wyman 1922), the annual return from gum was 80 per cent greater with shallow, low chipping on narrow faces than with deep, high chipping on wide faces. Liefeld (1942) found that turpentined trees have a longer working life under a schedule of semiweekly chipping in summer, weekly chipping in spring and fall, and semimonthly chipping in winter than under schedules of more frequent chipping. The decrease in mortality of turpentined trees which results from conservative technics should make it easy to maintain enough stems—150 per acre at 30 years and 100 in the latter part of the rotation—to make operations profitable at all times (Ziegler and Bond 1932).

The application of chemicals to the newly cut streak is proving profitable. A 40 per cent H_2SO_4 solution on slash pine and a 60 per cent solution on longleaf pine, when applied to streaks cut weekly and extending only through the bark (not into the wood), produce the maximum yield of gum. On such a schedule gum yield for the season has been 40 to 70 per cent greater than on trees not treated with H_2SO_4. On the other hand, if streaks and acid are applied every 2 to 3 weeks, gum yield is approximately equal to that from trees chipped weekly but not treated with acid. The 2- to 3-week schedule with acid treatment is most economical of labor (Snow 1946).

Application of Methods

Except for the systems used to regenerate mature stands, the methods of treating longleaf pine stands must be determined by the objective of management—whether to produce chiefly saw logs and pulpwood or chiefly naval-stores products. The methods of treatment are outlined below on the basis of these two broad objectives.

Saw-Log and Pulpwood Management. *Seed-Tree Cutting and Clearcutting.* Existing evidence indicates that the seed-tree method of cutting is the most practical for longleaf pine stands. It has the advantage of providing an adequate seed supply at the minimum cost and the least possible interference with regeneration. The method is

most likely to be effective on the better sites (Fig. 35). At least four, and preferably six to eight, trees per acre between 13 and 17 inches d.b.h. should be left. These trees, uniformly distributed over the cut-over area, should be thrifty and have large, well-developed crowns. Chapman (1941) believes that, on dry sites in the western part of the range of longleaf pine, grouping of the seed trees is advantageous

Photograph by U. S. Forest Service.

FIG. 35. Abundant reproduction generally follows seed-tree cutting in mature longleaf pine stands on good sites. On many sites prescribed burning may be necessary to prepare the site for reproduction.

in order to confine the competition from the overstory to a smaller area.

Clearcutting followed by planting appears to have merit on poor sites, but it cannot be recommended until improved planting technic can assure better survival of planted trees than is now secured.

Use of Fire to Promote Reproduction. Accumulated evidence demonstrates that prescribed fire is an essential tool in securing a satisfactory stand of natural reproduction (pp. 201 and 202). In addition, it is an effective fire-protection tool (Simerly 1936, Squires 1947). Several years of experience with large-scale prescribed burning for fire protection provide a reasonably satisfactory precedent for its application as a silvicultural tool. The details of prescribed burning technic are described fully by Bickford and Curry (1943).

The time for the first burning must be carefully chosen in relation to the time of logging. Areas that are to be logged during spring, summer, or fall can best be burned during the winter prior to logging, or the winter preceding a good seed year, if this is not too far in advance of cutting. On winter-logged areas burning should be done soon after the cutting, while the slash is still green. Although the second burning should occur 3 years after the first, this is not practicable if the slash is not disposed of by fire; consequently, the second burning generally must be postponed until the slash has deteriorated, usually in 4 to 5 years. Subsequent burnings should be determined by the condition of the reproduction and other factors.

Degree of fire hazard must be an important consideration. In turpentined stands extreme caution must be exercised to prevent any defoliation, because defoliation decreases the yield of oleoresin (Gerry 1931*b*). On the other hand, a prescribed burn that destroys the living and dead surface cover but does no damage to foliage increases the gum yield slightly in the succeeding year (Harper 1944).

Prescribed burning can be applied to selectively cut stands without danger of severe damage to the residual trees since all, except the very young longleaf pines, are quite fire-resistant. Site preparation prior to burning is essential to keeping the fire under control.

Where control of the brown-spot needle blight is involved, burning is futile unless an area of at least 10 acres can be burned at one time (Siggers 1934).

Cultural Operations. Thinnings, according to the plan outlined for the loblolly pine–shortleaf pine types (p. 228), should be made in well-stocked stands. Heavy thinnings are essential, especially if the timber is to be used for pulpwood (Demmon 1936), but they should not be so heavy as to result in a growth rate that will impair the wood's usefulness (Koehler 1938).

Pruning is recommended for the crop trees in open-grown stands managed for saw logs. If pruning is to be completed in a single operation, the trees should be at least 34 feet tall before they are pruned (Bull 1943). If pruning is to be done in two operations, it may begin when the trees are 18 feet tall. Below a height of 8 feet above ground, a hand pruning saw with a slightly curved 14-inch blade with five and one-half to eight teeth per inch is best (Bull 1937). Between 8 and 17 feet above ground, a pole saw with a 16-inch blade having seven teeth per inch and cutting on the draw stroke is recommended for trees under 5 inches d.b.h. At the same height, trees 5 to 8 inches d.b.h.

can be pruned effectively either with a pole saw or by handsaw and ladder. Trees over 8 inches d.b.h. are pruned best by the latter method, especially if the trees have large limbs.

Cultural operations are necessary in those stands of the longleaf pine–turkey oak type in which more than twenty longleaf pines per acre need release and less than 200 pines per acre are free (Staff of the Southern Forest Experiment Station 1933). The oaks, the chief offenders, that are crowding, overtopping, or threatening to overtop young pines should be removed—those 5 inches d.b.h. or more, by girdling or poisoning; and those under this diameter, by cutting. Release should extend to a radius of 6 feet from the pines.

Cleanings are necessary in the other longleaf pine types wherever controlled burning does not adequately control the low-value hardwoods and shrubs. Release should be frequent, occurring whenever the tree sprouts attain the height of the pine seedlings.

Planting. Forest planting is requisite to the establishment of forest cover on a vast area of denuded land. Longleaf pine is best for the bulk of the land formerly occupied by this species, although slash pine can be planted on many of the sites having a comparatively shallow surface soil of sand or sandy loam overlying a stratum of rather stiff sandy clay, provided rainfall and temperature resemble that of the natural range of slash pine (Wakely 1935). One-year seedlings are recommended for general use.[4] Spot planting, using a scalped area 12 to 15 inches in diameter, is best for longleaf pine since it minimizes damage from silting; furrow planting is preferable for slash pine planted on dry, sandy, or grass-covered sites (Wakely 1935). On brush-covered sites, the brush should be cut before planting when longleaf pine is employed, and before or 2 to 3 years after planting when slash pine is used. Spacing should be 6 by 6 to 8 by 8 feet if only saw logs are to be produced without thinning, 6 by 6 to 6 by 8 feet if saw logs and pulpwood are to be the products. Relatively close spacing is recommended for longleaf pine because initial mortality of planted trees is usually high. Where naval stores are to be the primary product, a spacing of 8 by 8 feet is probably best. The planting should be done with a planting bar during December and January, in the

[4] Grade 1 seedlings (longleaf pine with vigorous and abundant fascicled needles 10 or 12 to 18 inches long, slash pine 10 to 16 inches tall) should be used on adverse sites or where competing vegetation is heavy. Grade 2 seedlings (longleaf pine needles 8 to 12 inches long, slash pine mostly under 10 inches tall) can be employed on favorable sites.

Gulf States and a little farther north, an attempt being made to time the planting to avoid drought and frost.

Plantations must be adequately protected from fire, sheep, goats, insects, and disease (see pp. 215, 216).

Naval-Stores Management. The recommendations made here for the longleaf pine types apply also, with the exceptions noted, to slash pine stands operated for naval stores.

The first requisite to success in a naval-stores operation is to secure and maintain a well-stocked stand. Methods of securing adequate reproduction are dealt with elsewhere (p. 209, longleaf pine types; p. 237, slash pine types).

Thinning. In fully stocked stands thinning must begin early—before the trees are salable. The most practical method yet proposed of combining low cost and desirable effect appears to be the chosen-tree method (used in slash pine), whereby a single thinning at 8 years releases 200 of the best trees per acre on a radius of 5 feet (Akerman 1929). As young stands reach the stage at which they contain considerable numbers of 7- and 8-inch trees that might be taken out in thinning, selective cupping provides an opportunity of obtaining additional revenue from trees that will be removed in pulpwood thinnings. Such trees should be "bark-chipped" and the streaks treated with sulphuric acid, as described later. Thinnings should aim to have a stand density of 150 trees per acre at 30 years.

Technic of Facing. Turpentining may be practiced with or without the application of acid to the streaks. Since profits can be greater with acid treatment, this method is recommended, especially if savings in production cost are essential. If the acid treatment is not used, the following rules should be followed (Fig. 36).

1. Work only trees above 9 inches d.b.h. If a sufficient number of trees is available to allow raising the minimum diameter, it is more profitable to raise the diameter to 11 or 12 inches (Fogelberg 1942).

2. Place only one face per tree at a time on trees under 14 inches d.b.h., and no more than two faces simultaneously on any tree. A face should be no more than one-third the breast-height circumference of the tree in width, and it should never be over 12 inches wide no matter how large the tree.

3. Prepare new faces preferably in December or early January, never later than early February, by cutting the advance streak on the tree. The faces should be started within 7 inches of the ground.

4. Increase the height of the face not more than 8 to 16 inches annually, using 32 or more streaks.

5. In average second-growth stands, make the streaks ½ inch deep in slash pine and ¾ inch deep in longleaf pine. In old-growth timber of either species, streaks should be ½ inch deep.

6. Make the vertical height of the streak ¼ to ½ inch, never more than ½ inch. Careful use of sharp No. 0 hacks and pullers will keep streaks low.

7. Chip longleaf pine faces semiweekly during July and August, semimonthly from November to March, and weekly during the remainder of the year. A similar schedule is applicable to slash pine but with longer intervals between chipping (Harper and Wyman 1936).

Photograph by U. S. Forest Service.

Fig. 36. An open second-growth longleaf pine stand being worked for naval stores, using the American face. Trees less than 10 inches d.b.h. should not be worked.

If acid is to be applied to the streaks, the foregoing technic should be modified somewhat. Streaks should be kept from penetrating the wood (a method of cutting referred to as bark chipping). The streak in bark chipping is made with a single cut across the width of the face (Fig. 37). These streaks should be at least ½ inch high. Frequency of application is dependent on the operator's management objective. If he wishes the most economical operation, streaks should be cut every 2 to 3 weeks; if he desires maximum yield, streaks should be made weekly. In either case the acid should be applied carefully so

that is covers the entire cut surface. In longleaf pine stands a 60 per cent H_2SO_4 solution, in slash pine stands a 40 per cent H_2SO_4 solution, and in mixed stands a 60 per cent solution should be used.

Perpetuating a Turpentine Stand. Although protection from uncontrolled fire and grazing allows some reproduction to become established in a turpentined stand, it usually is necessary to reproduce the stand at the end of the turpentine rotation by the methods previously outlined.

Photograph by U. S. Forest Service.

FIG. 37. By bark chipping and the application of sulphuric acid to the streaks, the maximum yield of oleoresin is produced with the minimum labor.

Planting. Planting should follow the same general plan as for sawlog and pulpwood management (p. 211) except that the tree spacing should be 10 by 10 or 12 by 12 feet.

Slash Disposal

Slash is generally light except in dense stands that have been thinned heavily. The rapid deterioration caused by the humid climate makes the slash hazard short-lived. The sapwood is completely rotted in 2 or 3 years if it rests on or near the ground. Slash burning is therefore unnecessary as a general rule. Pulling heavy accumulations of slash 15 to 20 feet away from seed trees constitutes adequate fire-hazard-reduction treatment except on those localized areas near logging camps where the fire hazard is much higher than elsewhere; here piling and burning of the slash is advisable.

Disease and Insect Problems

Ecological Basis

The *turpentine borer* is the most serious insect pest of the longleaf pine types, attacking both longleaf and slash pine, especially turpentined and fire-damaged trees. The amount of infestation is related to the method of facing the trees, being least in trees faced by methods that most effectively conserve the tree's vitality (Beal 1932, Gerry 1931*a*, Wyman 1932). Greater checking of the wood of the faces under the less conservative turpentining methods provides the female beetle an ideal environment for laying her eggs, which she deposits in the cracks, and is thus responsible for the higher infestation. The insect causes serious damage by tunneling extensively in the trunk, rendering much of the butt log practically worthless commercially. Severely infested trees may be so seriously weakened mechanically that they are broken during wind storms; thus the entire tree is lost unless utilized promptly.

The *southern pine beetle* occasionally attacks the longleaf pine types, but rarely is the infestation severe.

Ips beetle infestations sometimes become severe after fire, drought, or turpentining, killing many trees of pole size or smaller.

Le Conte's sawfly, a defoliator, does some damage to trees of reproduction size, rarely on an extensive scale, however.

Red-brown butt rot occurs chiefly in fire-damaged trees. *Red ring rot*, a rot of older trees, enters chiefly through dead branches. Extensive loss of merchantable timber from these causes is limited to old-growth timber.

The *brown-spot needle blight*, a disease of the foliage of reproduction, is discussed elsewhere (p. 201).

Control Methods

Good silviculture and the control of fire are the secrets of keeping damage from insects and diseases at a minimum.

Conservative turpentining methods (see p. 212), keeping the chipped faces coated at all times so that the wood does not crack, and fire prevention are essential to the control of the turpentine borer (Beal 1932). Once a tree is attacked by the borer nothing can be done to save it.

Other insects and diseases, except the Le Conte's sawfly, which can be controlled only by an arsenate of lead spray, can be held in check by maintaining a thrifty stand and controlling fire.

Control of Animal and Logging Damage

Unless domesticated hogs are fed they must be excluded from the woods (see p. 202). To protect longleaf pine from wild hogs or domesticated hogs that are not fed on farms, fencing of the areas is necessary in order completely to exclude these animals.

Except during the first year of the longleaf pine seedling's life, when mortality of seedlings due to browsing and trampling by cattle is high, moderate to heavy grazing by cattle is desirable as an aid in the establishment of reproduction (Wahlenberg 1935). To secure the maximum benefit from cattle grazing, it should be heavy the year prior to seed fall, very light or excluded for a year or two, and then resumed on a normal basis (Wahlenberg 1937). Light damage to reproduction can be tolerated if the grazing yields a profit.

Control of logging damage is relatively simple, because advance reproduction is usually sparse and the reserve stand left after cutting consists chiefly of seed trees. Care must be exercised in logging to protect these elements, which are so important to the new stand.

LOBLOLLY PINE–SHORTLEAF PINE TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. This group of forest types is the most widely distributed of any in the region. It includes forests that vary widely in composition but silviculturally have much in common. Only those forest types in which shortleaf pine and/or loblolly pine predominate in number or commercial value are discussed here; forest types containing as many valuable hardwoods as pines are more important in other regions and are therefore discussed elsewhere (pp. 106, 175). The six types described in Table 15 are the most valuable loblolly pine–shortleaf pine forests.

Second-growth stands, now the prevailing type, are nearly always even-aged, usually dense, and productive of large volumes (Fig. 38).

Cut-over lands are variable in composition and stocking, the character of the residual stand depending largely upon the commercial value of the original stand. Where pine or pine and valuable hardwoods dominated the original stand, the cut-over land has a sparse growth of small pines and valuable hardwoods and of large and small low-value hardwoods. Where low-value hardwoods dominated the

TABLE 15

Description of the Loblolly Pine–Shortleaf Pine Types

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Loblolly pine–shortleaf pine	Major	High	Variety of soils in northern Mississippi and Louisiana	Loblolly pine and shortleaf pine may be the only species	Hawthorn Persimmon Black tupelo Post oak Red oak Sweetgum	Subclimax type succeeded by hardwoods (Committee Report 1932)
Loblolly pine	Major	High	Largely on old field or cut-over areas of the longleaf pine flatwoods type. Also on a variety of soils on Coastal Plain from Delaware and Maryland to Mississippi, Louisiana, and eastern Texas.	Loblolly pine, sometimes pure	Varies with site and locality. Any of following: Sweetgum Southern red oak Post oak Blackjack oak Black tupelo Water oak Yellow-poplar Pond pine Water tupelo Laurel oak	Temporary type on abandoned fields and probably a subclimax type elsewhere (Committee Report 1932)
Loblolly pine–southern red oak	Minor	Moderate to low	A variety of soils in central and northern Louisiana and southern Arkansas	Loblolly pine Southern red oak	Shortleaf pine Sweetgum Longleaf pine Post oak Persimmon	Gradual replacement by southern red oak (Committee Report 1932)
Shortleaf pine	Major	High	Well-drained ridges in the hills and low mountains of Arkansas, Texas, Oklahoma, Mississippi, and Alabama	Shortleaf pine, often pure on old fields White oak Southern red oak Black oak	Various hickories Post oak Blackjack oak Black tupelo Red maple	Climax type on certain sites; on others, superseded by red and white oak (Committee Report 1932)
Shortleaf pine–post oak	Minor	Moderate	Approximately the same as shortleaf pine type	Shortleaf pine Post oak	Scarlet oak Blackjack oak Black oak White oak Virginia pine Various hickories	Unknown
Shortleaf pine–southern red oak–scarlet oak	Major	Moderate	Dry sites on plateaus	Shortleaf pine Southern red oak Scarlet oak	Black oak White oak Post oak Black tupelo Various hickories Pitch pine Virginia pine Blackjack oak Mountain pine	Unknown

Photograph by U. S. Forest Service.

FIG. 38. Fully stocked second-growth loblolly pine stands yield large volumes of timber. Hardwoods develop in the understory at an early age.

original stand, the cut-over stand is usually two-storied, the low-value hardwoods overtopping the smaller pines and valuable hardwoods. Cut-over land that has been burned is more sparsely stocked and supports less pine than unburned land. The bulk of the cut-over loblolly pine–shortleaf pine forest is in one of these deteriorated conditions. A small acreage is well stocked with young growth and, for the most part, dominated by the pines.

Small areas of selectively cut forest are intermediate in character between the virgin and heavily cut cut-over lands.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction of several species is present in most mature loblolly pine–shortleaf pine stands, but it is sparse and irregularly distributed. Shortleaf pine and the more tolerant hardwoods constitute most of the reproduction in the denser stands. In recently burned stands, shortleaf pine and any of the hardwoods make up the reproduction, loblolly pine being absent because it does not sprout. A new stand must come chiefly from subsequent reproduction.

Subsequent Reproduction of Loblolly Pine. Authorities, although differing in their estimates of the frequency and size of loblolly pine seed crops (this difference probably being due to the difference in the localities studied), regard this pine as a good seed producer, some seed being borne every year and full crops at intervals of 2 to 4 years (Ashe 1915, Cope 1926, Mattoon 1926, Sterrett 1914, Zon 1905). Studies elsewhere (see p. 176) have shown a similar pattern of seed production. The number of seed trees per acre needed to insure adequate seed for prompt full reproduction has not been definitely established. Chapman (1942), as a result of his studies in Arkansas and Louisiana, is of the opinion that four trees per acre between 10 and 14 inches d.b.h. with crown lengths averaging 40 per cent of the tree's height are adequate if the seed bed can be put into ideal condition by burning. An Alabama study (Brinkman and Swarthout 1942) indicates that ten trees per acre are needed for prompt complete regeneration. Both Chapman and Gemmer (1941) emphasize the importance of exposure of the mineral soil for maximum germination and initial establishment of loblolly pine, but they differ as to the best means of achieving this exposure. Gemmer favors cultivation or raking to burning, whereas Chapman is a strong advocate of burning because of its effectiveness in creating a favorable seed bed as well as in ridding the site of low vegetation that, if not destroyed, would interfere with the development and even the survival of loblolly pine seedlings. Bull

and Reynolds (1943), without presenting experimental evidence, disapprove of burning. Chapman's (1942, 1945) studies in Arkansas and Louisiana demonstrate the importance of competition to the survival of loblolly pine seedlings. Under an overstory that is sufficiently open to allow the seedlings to maintain a height growth of more than 6 inches per year, loblolly pine seedlings survive for 10 to 20 years. Such seedlings are easily killed by fire, however. If loblolly pine reproduction does not become established within a year or two after cutting (and burning), thus allowing hardwood sprouts to gain considerable height, or if advance hardwood reproduction is not disposed of, the pine seedlings die in about 5 years. Grazing by cattle is detrimental to survival of loblolly pine seedlings during the first year after germination and may be harmful during the second season (Gemmer 1941, Chapman 1942).

Subsequent Reproduction of Shortleaf Pine. Shortleaf pine produces some seed nearly every year and full crops about every 3 years (Mattoon 1915). Trees below 12 inches d.b.h. do not bear large crops (Forbes 1930).

The character of the seed bed does not influence materially the initial survival of shortleaf pine seedlings, even the driest sites generally reproducing successfully. On dry sites shortleaf pine has a definite advantage over loblolly pine.

Although shortleaf pine reproduces by coppicing, this form of reproduction does not have practical significance in cutting operations, because only seedlings sprout. Where fire destroys a young stand, this sprouting characteristic is important in the quick re-establishment of forest cover.

Subsequent Reproduction of Hardwoods. Although most of the hardwoods produce large seed crops every 2 or 3 years, they fail to reproduce extensively from seed, because the existing seed beds are generally not favorable to their regeneration and, by the time the seed bed improves under fire protection, the pines and hardwood sprouts occupy the site so fully that hardwood seedlings generally fail to survive. A litter-covered soil is best for regeneration of most of the hardwoods, particularly the oaks. Only on areas protected from fire can this condition develop. Rodents are a limiting factor in the regeneration of heavy-seeded species—notably the oaks—from seed.

Since sprouts always follow the cutting of hardwoods, this form of reproduction promptly occurs wherever the hardwoods are cut. Their prompt establishment gives the hardwoods an immediate advantage

over the pines which may be more than temporary if there is any delay in the establishment of the pines.

Effect of Competition on Stand Composition. The ultimate representation of each species in the stand depends on the character and degree of competition it encounters and its ability to endure competition. Pure or almost pure even-aged stands of a single species of pine can be dismissed from the discussion since the ultimate composition, from the very nature of the case, cannot change noticeably. Retardation of growth in later years may result from overcrowding in such stands. Where shortleaf and loblolly pine are the dominant species, unrestricted competition is not likely to influence greatly the ultimate composition. If any species has an advantage, it is the loblolly pine because of its faster growth.

Where hardwoods constitute a substantial part of an even-aged reproduction stand, the future of the pine depends on the promptness with which pine reproduces after cutting and the presence of understory hardwoods and overstory pine and/or hardwoods. Survival of both shortleaf and loblolly pine in much of the region is imperiled if they do not reproduce within 2 to 3 years after cutting (Becton 1936, Chapman 1945). Hall (1945) concludes from 20 years of observation in southern Arkansas that hardwoods rarely prevent the establishment and development of shortleaf pine. Shortleaf pine is at a somewhat greater disadvantage than loblolly pine because its growth is slower. When advance hardwood reproduction is abundant, the pines have little chance unless the hardwoods are destroyed. If either advance or subsequent reproduction of hardwoods occurs in scattered clumps, competition is limited to a relatively few pines that will suffer some reduction in growth, and a few may die. In such cases the pines will maintain their representation under unrestricted competition.

In dense stands growth declines markedly at 20 years and high mortality is in evidence at 30 years.

In uneven-aged stands, such as selectively cut stands, the survival of the reproduction depends largely on the density of the residual stand. Pine seedlings can survive in large numbers only in openings. Under the residual trees some survive, but their growth is greatly retarded.

Windfall. Except on some of the poorly drained loblolly pine sites, where root development is superficial, and in the hurricane zones, windfall is a minor problem. The pines develop such a deep tap root, as do the oaks, that they have low susceptibility, even when a dense stand is cut heavily, thus exposing the trees to the full force of the wind.

Economic Basis

Utilization and Marketing Problems. *Relative Value of Species.* Table 16 shows the relative value of the important species in the loblolly pine–shortleaf pine types.

TABLE 16

The Relative Value for Commercial Wood Products of the Species of the Loblolly Pine–Shortleaf Pine Types

Commercially Valuable Species	Species of Little Commercial Value	
	Never Attain Saw-Log Size	Attain Saw-Log Size
White ash	American hornbeam	Pignut hickory
American beech	Flowering dogwood	Red maple
Eastern redcedar	Hawthorn	
American elm	Eastern hophornbeam	
Winged elm	Bluejack oak	
Black tupelo	Sassafras	
Sweetgum	Holly	
Bitternut hickory		
Mockernut hickory		
Evergreen magnolia		
Black oak		
Pin oak		
Post oak		
Shumard oak		
Southern red oak		
Water oak		
White oak		
Willow oak		
Loblolly pine		
Shortleaf pine		
Yellow-poplar		

Not only are the loblolly and shortleaf pine valuable for lumber but also they are the preferred pines of the South for pulpwood and they yield good cross-ties, poles, and piling. To be best qualified for pulpwood the wood should be relatively free of resin, have a small proportion of heartwood, and contain no knots. Such wood comes from relatively young (30 to 40 years) trees that have grown rapidly in stands in which the trees were closely spaced in the early years (Demmon

1936). The hardwoods are important chiefly for lumber, but many of them are valuable for cross-ties and some miscellaneous products.

Marginal Tree. Several studies of various phases of profitable utilization of loblolly and shortleaf pine for lumber, many of which have a bearing on silvicultural practice, have been made in recent years (Garver 1933; Garver and Cuno 1932; Garver, Cuno, Korstian, and MacKinney 1931; Garver and Miller 1933*a*, 1933*b*; Koehler 1938; Paul 1930, 1931, 1932*a*, 1932*b*; Reynolds, Bond, and Kirkland 1944). Summarized, they demonstrate the following:

1. In general, trees under 11 inches d.b.h. seldom yield a profit. In some instances, trees as large as 15 inches d.b.h. are cut into lumber at a loss. Second-growth timber shows a loss at a higher diameter than old-growth timber. In a comprehensive study in Arkansas, the per thousand realization values, based on 1940 values, ranged from $1.51 for 12-inch trees to $14.98 for 30-inch trees—a ratio of nearly 1 to 10 (Reynolds, Bond, and Kirkland 1944).

2. The greatest profit, on a per acre basis, usually results from cutting all trees above 10 to 11 inches d.b.h., although sometimes the lower limit is as high as 14 or 15 inches. The greatest profit per thousand board feet is realized by cutting to diameters varying from 15 to 20 inches d.b.h. These facts emphasize the importance of studying the individual timber tract.

3. The variation in profits from trees of different sizes, noted above, is due in part to wide differences in the quality of lumber produced by individual trees; e. g., one 15-inch tree may have a value of $2.25, another, a value of $0.40. The difference in quality causing this wide spread in values is due to such factors as stand density, the presence of old-growth hardwoods in the stand, thinning, and pruning of the stand.

4. Not only are the small trees uneconomical to handle, but also the waste in sawing them into lumber is large (the waste in sawing a 10-inch tree into lumber is 57 per cent; a 26-inch tree, 35 per cent (Garver and Miller 1933*b*).

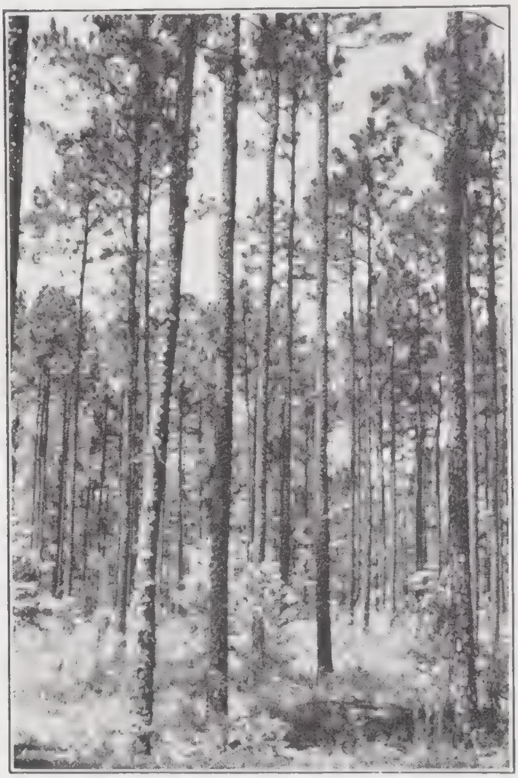
5. The best-quality lumber comes from stands dense enough in early life to cause self-pruning and open enough to allow moderately rapid growth. If growth is too rapid (less than four rings per inch), the wood will produce inferior lumber and the yield of pulp will be reduced.

6. Sawmilling methods influence the cost of converting saw logs into lumber and the quality of the final product, thus indirectly affecting the size of the marginal tree. Recent studies of loblolly pine indicate that a well-equipped portable band sawmill produces more lumber per unit of logs than a large band sawmill.

Hardwoods are less profitable than pines in all sizes, and they must have larger minimum diameters to yield a profit. In Virginia, hard-

woods 15 inches d.b.h. or less could not be handled at a profit, and, in the Arkansas study referred to above, the realization value ranged from \$1.61 for 12-inch trees to a maximum of \$6.93 per thousand for 23-inch trees with a decline to \$5.18 for 30-inch trees.

Profits from converting loblolly and shortleaf pine into pulpwood also vary with tree size, but the variations are less pronounced than for saw logs. Cost of producing pulpwood declines sharply on trees between 4 and 8 inches d.b.h., above which there is little change in cost up to a diameter of 15 inches d.b.h. Pulpwood can be produced from 8-inch trees for about two-thirds the cost of that from 4-inch trees. Four- and five-inch trees have essentially no stumpage value.



Photograph by U. S. Forest Service.

FIG. 39. An old field stand of loblolly and shortleaf pine which was thinned to 100 trees per acre at 43 years.

It is obvious from the foregoing that proper integration of pulpwood and saw-log production is a requisite to the most profitable operation of loblolly pine–shortleaf pine stands.

Growth and Rotation. On an average site, loblolly pine, the fastest growing species of the southern pines, produces at 50 years a mean annual growth per acre of 679 board feet (International ¼-inch rule), whereas shortleaf pine produces 492 board feet at the same age—approximately 72 per cent of the growth of loblolly pine (Forbes and Bruce 1930). According to Meyer (1942), yield of fully stocked even-aged stands of loblolly pine in northern Louisiana at 80 years varies from 21,800 board feet per acre, for site index 70, to 51,000 board feet, for site index 120 (also International ¼-inch rule). The production of high-quality saw logs requires a rotation of 60 to 80 years, whereas the production of profitable pulpwood crops requires a rotation of 30 years for loblolly pine and 40 years for shortleaf pine (Demmon 1936).

Increases in growth of loblolly pine following thinning, improvement cutting, or liberation cutting of 130 to 370 per cent have been reported by several investigators (Bull 1945, Chapman 1923, MacKinney 1933, Smith 1947). In one of these studies in a 10-year period, average diameter, basal area, and volume growth were nearly three, two, and five times as great, respectively, on the treated as on the untreated area (Bull 1945).

Growth rate following thinning is dependent more on the degree of thinning than on the kind of thinning. Relatively heavy thinning is essential to the maintenance of satisfactory growth (Barrett and Righter 1929) (Fig. 39). Chapman (1942) has found that satisfactory growth is dependent on a sufficiently large crown, which he finds should be not less than 40 per cent of the height of the tree. He reports that maximum growth can be maintained by keeping the basal area of the stand between 80 and 120 square feet per acre, the low figure applying immediately after thinning.

Financial Aspects. *Clearcutting vs. Selection Cutting.* A comparison between the relative financial advantages of clearcutting and selection cutting is not so simple as the mere figures on lumber-production and timber-growing costs might indicate. On sites where hardwoods do not constitute an ecological problem or in stands where tree size varies widely, selection cutting may be more profitable than clearcutting, when all factors are considered. Where these conditions do not prevail financial studies have not been sufficiently inclusive of all cost factors to make an accurate comparison. Hallauer (1930) found a lumber-production cost of approximately two-thirds as much under selection cutting as under clearcutting for shortleaf pine, and Garver (1933) found a saving of $1.18 per thousand board feet in growing loblolly pine saw logs under selection cutting instead of clearcutting. If these studies had been based on stands with different tree-size distribution or had considered the financial aspects of regeneration success or failure, the comparison might be somewhat different.

Cultural Operations. Cultural operations have proved their financial worth in loblolly pine–shortleaf pine stands. Although improvement cutting usually does not yield an immediate profit, there may be exceptions when diversified markets are near by as at Crossett, Arkansas. In this instance a net profit was made on both pine and hardwoods, the latter being utilized for chemical wood (Reynolds 1939*b*). Where the market will not absorb low-grade hardwoods, improvement cutting involving their disposal has required a minimum of 5 years to liquidate the cost of the work (Bull 1939). In one case

an investment of 2.3 man-hours of labor per acre in improvement cutting produced nearly three more cords of pulpwood per acre in 10 years, worth two to five times the cost of the work (Bull 1945). At the end of 7 years in another case it was predicted that a treated area would have $3.09 more pulpwood 20 years after treatment and $41.88 more pulpwood 40 years after treatment than an adjacent untreated area (Smith 1947).

The facts presented previously (p. 224) on the cost of pulpwood production from trees of various sizes suggest the possibilities of immediate profits from thinning. Young stands (15 to 20 years old) in which trees under 6 inches d.b.h. constitute the trees cut in thinning generally cannot be expected to yield an immediate profit from thinning.

Planting. Reynolds (1939*a*) made a theoretical calculation of the possible returns from planted loblolly pine. He predicted that at the end of 36 years costs would exceed returns, but that soon thereafter returns would exceed costs with ultimate annual returns reaching as much as $2.49 per acre at 52 years.

Application of Methods

The character of the stand and the site and economic considerations must govern the type of reproduction cutting used. Clearcutting or seed-tree cutting are best for overmature stands, stands in which virtually all the trees are above the size of the marginal tree, stands in which trees have small crowns owing to crowded stand conditions, and stands in which an understory of hardwoods will interfere with regeneration. Selection cutting is most applicable in stands that are relatively open, in stands containing few hardwoods, and in stands that are uneven-aged by groups. Silviculture should not yield to the demands of pulpwood buyers because, in the long run, timber production in which saw timber is the primary product is most profitable.

Seed-Tree Cutting and Clearcutting. These methods are particularly appropriate for areas that must be burned to create favorable conditions for regeneration. Other stand conditions that make seed-tree cutting or clearcutting suitable are outlined above. At least four trees per acre over 10 inches d.b.h., preferably 14 inches, with crowns having a length equal to not less than 40 per cent of the tree's height should be left. If the site is not ideal for regeneration, six or more trees per acre should be retained.

If suitable seed trees are not available, clearcutting is a more effective method than seed-tree cutting. Clearcut strips should be no more

than 300 feet wide. Adjacent uncut areas should be retained until the cut-over areas are adequately stocked.

Selection Cutting. Selection cutting appears feasible in many of the irregular stands where several age classes of pine are represented

Photograph by U. S. Forest Service.

Fig. 40. An uneven-aged stand of shortleaf pine that has been cut selectively.

or where valuable hardwoods are an important component (Fig. 40). Where pure pine management is the objective and as stands become fully stocked, even-aged management as described earlier should eventually replace selection cutting to a considerable extent. The latter method has merit in stands in which valuable hardwoods are

strongly represented. In selection cutting, the size of the marginal tree, stand improvement, and the reproduction needs of the stand should be taken into consideration. Reserve volumes should be large enough to make cutting cycles of 10 to 20 years possible.

Group-selection cutting is the form of selection cutting most likely to succeed on a permanent basis, because it creates the open site needed for pine regeneration and it makes prescribed burning feasible.

Prescribed Burning. To assure establishment and survival of pine reproduction wherever hardwoods are a component of the stand, control of the hardwoods is essential. The smaller ones (under 1 inch in diameter at ground) can be controlled by fire, whereas the larger must be controlled by cutting, poisoning, or girdling (Chapman 1947*c*). The prescribed burning can precede or follow the cutting, girdling, or poisoning of the larger hardwoods. If fire is applied first, the girdling or cutting should be deferred until a growing season has elapsed in order that damaged trees which may die during the first growing season will not be cut unnecessarily. Late August or early September is the best season for disposal operations by all methods, because the site is thus cleared just before seed fall and the seedlings that become established during the following season will get started under a minimum competition. A second burning to prepare the site for reproduction may be necessary if logging occurs during a non-seed year, because re-establishment of hardwoods during the period between the cutting and a seed year is likely to create a situation unfavorable to regeneration. Seed trees should be protected from fire by removing logging slash to a distance of 6 to 8 feet from the bole.

By applying prescribed burning every 10 years, control of the hardwoods can be accomplished throughout the life of the stand. Since sapling-sized loblolly pine (about 10 years old) and larger trees are sufficiently resistant to withstand prescribed burning, such periodic burning is feasible.

Thinning. With markets for pulpwood available in virtually every section where loblolly pine–shortleaf pine stands occur, the opportunity for applying commercial thinnings is excellent. It seems unnecessary to begin thinning before trees in stands are large enough for pulpwood. Chapman (1942) believes the first thinning can best be made when the dominant trees are 40 feet tall (15 to 22 years old). Opinions differ on certain details of thinning practice (Chapman 1942, Bull and Reynolds 1943), because research has not gone beyond the preliminary aspects of thinning. Bull (1935) developed detailed instructions for

thinning based upon existing and future markets, object of management, and the stage of natural pruning. Parts of his recommendations have been antiquated by the expansion of the pulpwood market. Certain portions of part *A* of Bull's recommendations would undoubtedly give results in stand growth and development similar to those of Chapman's recommendations, but Bull's suggestions are rather complex and difficult to visualize in terms of number of trees, basal area, and average spacing of the trees left.

Although a nonrevenue first thinning is not recommended for general application, it seems advisable when crowding in the stand is so intense that further postponement will so reduce crown size that growth will be curtailed. Thinning throughout a stand's life must be heavy enough to release the crop trees sufficiently to maintain a satisfactory crown (somewhere around 40 per cent of the total height of the tree). Basal area seems to be an excellent basis for gauging thinning. Chapman (1942) recommends thinning stands down to 70 to 75 square feet of basal area per acre. Greater flexibility in amount of basal area to allow for differences in site, stand, and management objectives seems desirable. It can probably be attained by varying the basal area per acre between 70 and 100 square feet. Thinnings should ordinarily be repeated every 5 to 7 years.

Liberation Cutting and Cleaning. Restoration of the vast area of old cut-over lands that have had no silvicultural treatment demands cultural measures and/or planting. Planting should be restricted to those lands that support little or no timber growth and have little chance of becoming reforested naturally.

The low-value trees in the overstory should be disposed of by girdling or poisoning unless the understory is poorly stocked, in which case overstory trees of the better species should be left to produce seed for restocking. Dense understories should be cleaned (Staff of Southern Forest Experiment Station 1933).

Planting. The need for planting is greatest on eroded and abandoned agricultural land; therefore, this land should have priority over other lands. Burned and otherwise deforested lands stand next in order. The technic and season of planting for shortleaf and loblolly pine can be the same as for longleaf pine (p. 211) except that furrowing, as used for slash pine, should have preference over scalping as a method of site preparation.

Loblolly pine should be planted on the sandy coastal plain from South Carolina north to Maryland and in the Piedmont Plateau from

Mississippi east to Georgia, thence north into North Carolina (Wakeley 1935). In general, it should be planted on the wetter sites, shortleaf pine on the drier sites. For eroded land and abandoned agricultural land outside the range of loblolly pine, shortleaf pine is probably best. Grade 1 one-year-old seedlings of both species should be used on sites that are of poor quality or support a heavy vegetative cover; grade 2 [5] 1-year-old seedlings can be used on good sites (Wakeley 1935). A study of geographic races of loblolly pine has demonstrated that planting stock produced from local seed makes better growth and has less rust infection in later years than planting stock from other sources (Wakeley 1944).

Proper spacing is still a controversial issue. Advocates of close spacing (6 by 6 feet) (Ware and Stahelin 1946) base the superiority of such spacing solely on the greater pulpwood volume, much of which is in 4- and 5-inch trees, which are costly to convert into pulpwood. They ignore also the practical consideration that mechanized logging, which cheapens logging, cannot be used where spacing is so close. Logging engineers contend that the trees must be spaced at least 10 feet apart. The author believes that some compromise which would allow a spacing of 7 to 8 feet between trees and wider spacing at intervals of several rows may be the most effective in terms of profit. For erosion control, spacing of 3 by 3 to 4 by 4 feet is necessary.

Using other species in mixture, planting on brush-covered sites, and avoiding the planting of large areas at one time, thus preventing the development of large even-aged plantations, especially on poor sites, are recommended precautionary measures against severe attack by the Nantucket tip moth (Wakeley 1935). Protection of the plantations from fire, sheep, goats, and rabbits is essential to successful establishment.

Slash Disposal

Slash in the loblolly pine–shortleaf pine types is highly hazardous during the first year or so, but thereafter the hazard decreases rapidly. The smaller branches of both hardwoods and pines are usually broken from the bole and fall to the ground in 3 to 4 years (Long 1917). The larger parts of the oak slash decompose at a slower rate; the heartwood remains reasonably sound for several years, but the large material

[5] Grade 1 shortleaf pines are 6 to 12 inches tall; grade 1 loblolly pines are 8 to 14 inches tall. Grade 2 stock of both species is mostly smaller but contains some seedlings as large as grade 1 seedlings.

is the least hazardous part of the slash. Lopped and scattered slash decomposes in approximately 1 year less time than unlopped slash.

Because of the similarity of the slash-fire hazard in this type to that in the longleaf pine type, the same method of disposal can be used (see p. 214), except that on eroding sites lopping and scattering of the slash is suggested if it appears that this treatment will aid effectively in erosion control.

Disease and Insect Problems

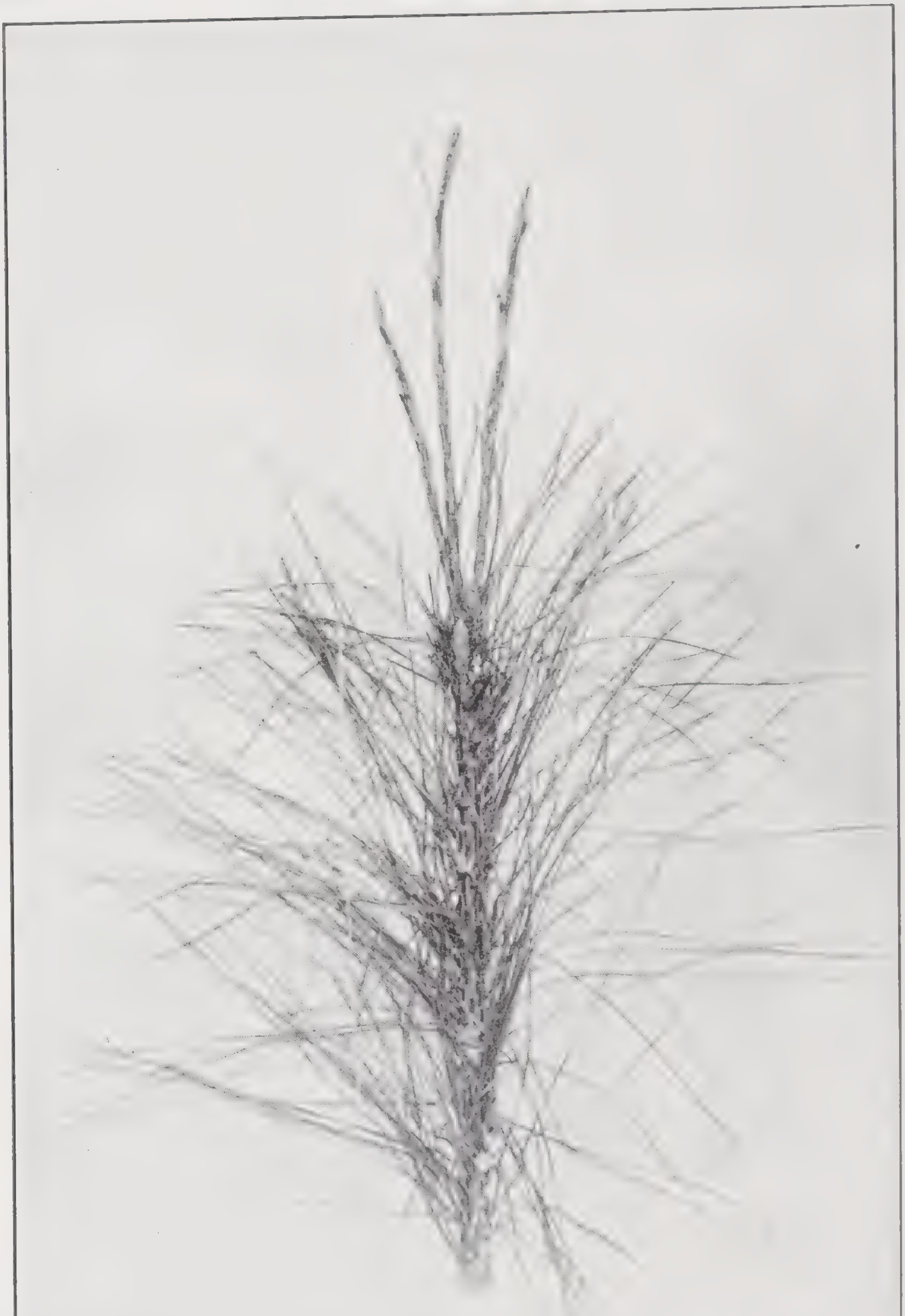
Ecological Basis

The *Nantucket tip moth*, an insect that attacks the leader of loblolly and shortleaf pine seedlings under 6 to 8 feet tall, causing a loss in height growth, does widespread damage (Forbes 1930, Hayes and Wakeley 1929) (Fig. 41). Seedlings exposed to full sunlight are most severely attacked; those growing in mixture with hardwoods are rarely infested. Large young plantations, especially on poor sites, often create a serious tip-moth hazard.

The *southern pine beetle*, a bark beetle, is somewhat of a menace to the pines but seldom becomes serious in the loblolly pine–shortleaf pine types of this region. The hazard is greatest in stands containing no hardwoods, especially dense stands where the trees have low vigor.

Red ring rot and *red-brown butt rot* have been identified in both loblolly and shortleaf pine. The former decay enters through branch stubs, and the latter chiefly through fire wounds (Hepting and Chapman 1938). In two stands studied by Hepting and Chapman, volume loss from rot ranged from 3.9 to 7.0 per cent. An intensive study by Garren (1941) of decay entering fire wounds in loblolly pine in Alabama revealed a loss of 25 to 40 board feet per tree where fire wounds were 7 to 12 inches wide and over 40 board feet per tree where wounds were over 12 inches wide.

Two rusts, the *eastern gall rust* and the *southern fusiform rust*, are discussed at this point because the loblolly pine is one of the most susceptible species to infection. Shortleaf pine, on the other hand, apparently has low susceptibility and longleaf pine is the most resistant, whereas slash pine is highly susceptible. Invasion of lands supporting "scrub oaks," the alternate host of the rusts, by loblolly and slash pine, the planting of infected stock (infection coming from scrub oaks adjacent to nurseries), and the planting of loblolly and slash pine on sites supporting scrub oaks have increased the damage done by those



Photograph by U. S. Forest Service.

Fig. 41. Loblolly and shortleaf pines under 6 to 8 feet tall are often severely damaged by the Nantucket tip moth when in an open stand or when large areas of these species contain few hardwoods.

rusts in recent years. Small trees are frequently killed, in extreme cases causing understocking.

The *little leaf disease*,[6] first reported in 1934, is causing considerable damage to shortleaf pine and minor damage to loblolly and Virginia pine. Trees are attacked after they reach 20 years and die in 5 to 7 years after visible signs of the disease are evident. Trees in dominant and codominant crown classes are more often attacked than those in other crown classes. As much as 50 per cent of the stand volume of shortleaf pine may be affected (Boggess and Newman 1947). Factors influencing the occurrence of this disease are unknown.

Le Conte's sawfly, *scale insects*, and a *twig canker* are minor insect and disease pests that kill occasional trees and cause decreased growth or deformation in others.

Control Methods

Prevention of infestation is the only practical method of controlling the Nantucket tip moth. Precautionary measures to be taken in connection with artificial reforestation were outlined previously (see p. 230). The development of fully stocked, reproduction stands with some hardwoods in mixture should prevent severe damage to natural reproduction.

When economically feasible, logging is the most practical method of combating serious infestation of the southern pine beetle. In such operations weak and unhealthy trees, as well as infested trees, should be removed to improve the general vitality of the stand and thereby increase its immunity (St. George and Beal 1929). When logging is impractical, the infestation can be put under control by cutting the infested trees, followed by removal and burning of the bark or by exposure of the felled trees to full sunlight.

The rusts can be controlled by taking care to plant trees free of infection, planting only on sites free of scrub oak, or, if scrub oak is present, by planting longleaf pine or possibly shortleaf pine if the site permits. In natural stands where scrub oaks are common, it seems advisable to favor longleaf pine (or perhaps shortleaf pine).

Until more is known about the little leaf disease, positive measures cannot be taken to control it. In areas where it is prevalent, salvage cutting every 3 to 5 years should prevent excessive loss of trees. Favoring species other than shortleaf pine, where they are adapted to the site, in cutting and planting should minimize future losses from the little leaf disease.

[6] Although referred to as a disease, a causative organism has not been isolated.

Control of the trunk rots is dependent on the maintenance of a fully stocked stand, its protection from fire and other injurious agencies, and the removal of severely infected trees in cutting operations.

The minor insects and diseases are not serious enough to demand control measures.

Control of Animal and Logging Damage

The drastic control of hogs outlined for the longleaf pine type is unnecessary in the loblolly pine–shortleaf pine forests because hogs do little damage in the latter. Control of cattle should follow the plan outlined for the longleaf pine type (p. 216).

In selectively cut stands horse or caterpillar tractor logging under strict supervision should be used. Where seed-tree cutting is applied, the method of logging is not particularly important, but it should be employed in such a way that advance reproduction and seed trees are preserved.

SLASH PINE TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. The slash pine types are characteristic of the southeastern part of the region, some of them extending as far west as eastern Louisiana, however. Two types—the slash pine and the longleaf pine–slash pine—are of outstanding value commercially. Three additional types—the cabbage palmetto–slash pine, the slash pine–swamp tupelo, and the loblolly pine–slash pine—constitute the remainder of the slash pine forest, but since they are of minor importance no further mention of them will be made. The slash pine and longleaf pine–slash pine types are described fully in Table 17.

Second-growth forests are the prevailing slash pine types. Many of the stands are between 10 and 20 years old, having become established as a result of the expanded and improved fire protection of recent years. Dense pure stands of slash pine have gained control of lands formerly occupied by longleaf pine forests.

Stand Regeneration and Development. Advance reproduction of slash pine is limited to the more open parts of mature stands, but even there it is not abundant. Some hardwood reproduction is usually present.

Subsequent Reproduction. Limited study indicates that, under protection from fire, slash pine reproduces with relative ease owing to its

heavy seed production and the ability of its seedlings to withstand a moderate amount of competition from other vegetation. Slash pine produces some seed nearly every year and heavy crops every 3 to 5 years.[7] Two 13- to 17-inch d.b.h. trees, or four smaller trees, per acre should produce enough seed for a full stand of reproduction. The seed is disseminated 300 feet in moderate winds and approximately 1000 feet in strong winds (Mattoon 1922).

TABLE 17

DESCRIPTION OF THE SLASH PINE AND LONGLEAF PINE–SLASH PINE TYPES

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Slash pine	Major	High	Chiefly on old fields and in shallow ponds on branch bottoms of flatwoods	Slash pine, ordinarily pure	Pondcypress Swamp tupelo Red maple Sweetgum Sweetbay Loblolly-bay Water tupelo Pond pine	Subclimax type
Longleaf pine–slash pine	Major	High	Borders of ponds on soil intermittently wet and longleaf pine ridges in the flatwoods or in old fields	Longleaf pine Slash pine	Water oak Laurel oak Post oak Blackjack oak Live oak	Temporary type, probably followed by longleaf pine

Germination of slash pine seed is substantially increased by preparation of the seed bed but not so much as that of longleaf pine (Osborne and Harper 1937). An unprepared seed bed is no handicap, however, because the author has observed that slash pine tends to reproduce too abundantly for the best development of the young stand. Slash pine regeneration apparently needs discouragement through nonpreparation of the seed bed more than stimulation through seed-bed preparation. This fact does not apply where dense, tall shrubs become firmly established before slash pine reproduction. Once established, slash pine seedlings have a distinct advantage over longleaf pine seedlings on grass-covered sites because of their ability to grow moderately fast in

[7] According to M. B. Wilder, a seed collector at Lake City, Florida.

spite of the vegetation. High soil-moisture content, once regarded as essential to the establishment of slash pine seedlings, apparently is not a requisite, as evidenced by the prolific natural reproduction under fire protection and the successful plantations of this species on dry longleaf pine sites.

Slash pine seedlings are relatively immune to damage by cattle or hogs. However, observation of severe damage to slash pine seedlings by hogs has occasionally been reported. Rabbits, biting off the leaders, are the most damaging animals, in extreme cases injuring 80 to 85 per cent of the trees in plantations on sites supporting a heavy shrub cover (Hayes and Wakeley 1929).

Uncontrolled fire gives longleaf pine and hardwood reproduction an advantage over slash pine seedlings—the longleaf pine because it survives the fire, and the hardwoods because they recover quickly by sprouting.

Growth and Competition. Open-grown slash pine seedlings grow rapidly from the start, attaining a height of 8 to 12 inches by the end of the first year, and 6 to 10 feet in 3 to 5 years. Thereafter, growth is 2 to 3 feet per year (Mattoon 1922). In dense stands competition becomes intense by the tenth year or earlier. Whether this is likely to lead to stagnation is not known. There has been no study of the growth of these stands, but some foresters believe that slash pine expresses dominance sufficiently well to prevent growth stagnation. The author is not convinced that this is so. Wherever slash pine seedlings become established as soon as seedlings or sprouts of other species, it can more than hold its own in competition because of its rapid early growth.

Windfall. Young slash pine stands are quite susceptible to windfall. In the older stands susceptibility to windfall damage is greatest in the hurricane zone and on soils that are underlain by hardpan. Windbreakage is significant in turpentined stands.

Economic Basis

Except for differences in rate of growth and rotation, the economic factors influencing the silviculture of the slash pine types are essentially the same as in the longleaf pine types (see p. 203). At the culmination of growth, which occurs at 50 years, slash pine has an average annual growth per acre of 507 board feet, International ⅛-inch rule. The rotation for saw timber should be somewhat longer than 50 years to produce high-quality saw logs. A rotation of 30 years yields good

pulpwood (Demmon 1936), but it is uneconomical to make it the primary product in timber production.

Application of Methods

Research has been insufficient to indicate any specific details of management for the slash pine type that should differ from those outlined for the other pine types. Cutting methods for regeneration purposes should be the same as for the loblolly pine–shortleaf pine types (see pp. 226 and 227). It is doubtful that prescribed burning is needed as an aid to reproduction except where tall, dense shrubs are firmly established. Thinning and other cultural measures in stands managed for saw logs or pulpwood should also follow the plan outlined for the loblolly pine–shortleaf pine types. Stands managed for naval stores should be handled in the same way as the longleaf pines managed for this purpose (see p. 212).

Planting technic should be the same as for longleaf pine except for spacing. A spacing of 10 by 10 feet appears most suitable for slash pine.

Miscellaneous Silvicultural Problems

Where prescribed burning is used as a fire-protection measure, the first burning should be delayed until the trees are large enough to survive fire. Although this size has not been established by research, it is believed that trees over 15 feet are not likely to be seriously injured by prescribed burning carefully applied.

Slash can be handled the same as in the longleaf pine types.

The turpentine borer (see p. 215) is the most damaging insect pest of the slash pine types. The other insects and diseases (p. 215) that injure the longleaf pine type harm the slash pine types similarly. In addition, the same rusts that are so menacing to loblolly pine cause considerable damage to slash pine, the latter species ranking next to loblolly pine in order of susceptibility. The insect and disease pests can be handled by methods outlined previously.

ATLANTIC WHITE-CEDAR TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest. Although occurring also outside the southern pine region, the Atlantic white-cedar type is more

widely distributed here than in other regions. It is therefore discussed at this point.

Importance.
 Area—Minor, occurring in small detached tracts.
 Commercial Value—High.
Sites Occupied—Poorly drained swamps of peat underlain by a sand or clay subsoil.
Associated Species.
 Major—Atlantic white-cedar, often pure.
 Minor—Red maple, pond pine, baldcypress, swamp tupelo, sweet bay, redbay, loblolly-bay, slash pine, spruce pine, buckwheat-tree. Loblolly pine and yellow-poplar sometimes occur locally.
Place in Succession—A temporary type, replaced slowly by swamp hardwoods, especially where the subsoil is predominantly silt or clay (Buell and Cain 1943).

Atlantic white-cedar occurs in dense even-aged stands, with trees of many sizes represented. A dense understory of shrubs and pines is also characteristic.

Stand Regeneration and Development. Since advance reproduction of Atlantic white-cedar as well as its associates is practically nonexistent in mature stands, a new stand must develop almost entirely from subsequent reproduction.

Subsequent Reproduction. Atlantic white-cedar is a good seed producer, usually bearing some seed at 20 years, and later in life producing large crops nearly every year (Korstian and Brush 1931). The seed, being small, is disseminated widely by wind, in strong winds to a maximum distance of 1 mile. It remains viable in the forest floor for at least 1 year (Korstian 1924).

Excessively wet and excessively dry sites are unfavorable to cedar-seedling establishment. Dense slash or a heavy cover of vines and shrubs impede, or may even prevent, the establishment of Atlantic white-cedar seedlings. Slash tends to favor the hardwoods, particularly sprouts of these species, because they can force their way through the slash; cedar seedlings cannot. A warm, open site, well supplied with moisture, is an ideal habitat for profuse establishment of cedar seedlings. A leaf blight infects some cedar seedlings and saplings, killing a few, but it is not damaging enough to be a limiting factor in successful regeneration (Korstian and Brush 1931).

A light fire when the site is dry may give pond pine an advantage in regeneration in the Virginias and in the Carolinas and the slash pine an advantage in the Gulf States, owing to the ability of the larger

trees of these species to survive such fire (Korstian 1924). A severe fire that burns deeply into the duff and kills the larger pines causes replacement by swamp hardwoods, chiefly water tupelo and red maple. A fire that burns when the site is inundated does not change the composition of the reproduction.

Atlantic white-cedar makes more rapid height growth than most of its hardwood and conifer associates and is thereby able to hold its own in competition with them if they did not become established first. Pond pine grows faster than cedar, but only locally is it sufficiently abundant to offer serious competition to the cedar. If the stand is fully stocked, closure of the canopy occurs in 10 to 15 years, after which growth of the cedar is substantially reduced and numerous trees die, apparently because of decreased tolerance of the cedar at this age.

Windfall. Although its root system seldom extends more than 1 or 2 feet below the surface, Atlantic white-cedar suffers little damage from windfall in uncut stands. In New Jersey windfall loss in thinned stands was light and was confined chiefly to strips along the edges of stands (Moore and Waldron 1940).

Economic Basis

Although Atlantic white-cedar finds its largest market as poles, it can be marketed sometimes as shade-tree stakes, arbor poles, fence posts, cabin logs, and bean poles. The latter product is usually cut at a financial loss (Moore and Waldron 1940). In one instance in New Jersey a profit of $37.00 per acre was realized from a thinning that removed chiefly trees 2 inches d.b.h. and larger. It was concluded that with improved logging and supervision the profit might be increased to $100 per acre (Cottrell 1930) (Fig. 42). Net annual return from stumpage has been calculated at $2.94 to $4.17 per acre.

In stands between 36 and 65 years old on relatively poor sites growth in thinned and unthinned stands was 2.6 to 8.1 and 2.5 to 4.2 per cent respectively (Moore and Waldron 1940).

Application of Methods

Strip clearcutting—the length of the strips at right angles to the wind—with the strips not exceeding 1000 feet in width is the most practical method of reproducing Atlantic white-cedar stands. The uncut timber adjacent to the cut-over area should be left standing until at least one seed crop has been produced.

Any low-value hardwoods that are not cut should be disposed of by girdling or poisoning.

Young stands that contain a considerable quantity of hardwoods must be cleaned—preferably between the fifth and tenth years. Thinnings must follow cleaning. If small material such as bean poles (1 to 2 inches in diameter and 8 feet long) can be marketed, the first thinning can be made between the fifteenth and twentieth years. Subsequent thinnings should follow at intervals of 8 to 10 years. In the absence of a market for such small material, thinning will have to be

Photograph by U. S. Forest Service.

Fig. 42. By careful planning young Atlantic white-cedar stands can be thinned profitably.

postponed until salable material can be removed, because thinning cost is high. Moore and Waldron (1940) believe that thinnings are justifiable only on areas of site index 45 or higher and where stocking is at least 200 square feet per acre. They believe that on good sites containing 250 square feet per acre of basal area, thinning produces satisfactory results if postponed to the fiftieth year. Thinning for the stand as a whole should remove 35 to 40 per cent of the basal area, but it should be light along the edges of a stand.

Slash Disposal

Disposal of slash in the Atlantic white-cedar type after reproduction cuttings is necessary to gain silvicultural advantages rather than to

reduce the fire hazard. The slash, although heavy and decomposing slowly, does not constitute a serious fire hazard, two factors mitigating against it. In the first place, the swamps are generally wet, and, in the second place, forest cover usually re-establishes itself quickly after cutting—both of these conditions contributing to low inflammability. Heavy slash is detrimental silviculturally; it retards the establishment of Atlantic white-cedar seedlings but causes little interference with the establishment of hardwood reproduction.

Disposal should take the form of broadcast burning, the burning to be done during the first winter after logging when the swamp is full of water or sufficiently wet to prevent the destruction of the surface peat, which often contains much cedar seed (Korstian and Brush 1931). If burning cannot be done within the first year after cutting it is best not to dispose of the slash and, instead, to protect the area intensively for 5 to 10 years.

Disease and Insect Problems

Disease and insects are not sufficiently damaging to demand special attention. A heart rot, one of the brown pocket rots, caused by *Trametes subrosea,* is the most injurious pest, particularly if the rot extends into the roots, when it is a cause of windfall. Trees under 40 years old are seldom infected (Korstian and Brush 1931).

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7 · *Southern Bottomland Hardwood Region*

DESCRIPTION AND HISTORY

Location and Landownership

The southern bottomland hardwood region includes only a part of the South that is dominated by hardwood forests, namely, the area characterized by the typical forests of the alluvial bottomlands. The largest area—13,000,000 acres of forest [1] out of a total land area of 32,000,000 acres—is in the Mississippi Delta region (Fig. 1). An additional 17,000,000 acres of swamps, bays, ponds, river bottoms, and branch heads, scattered through the southern pine region, especially in the naval-stores section, support swamp hardwoods or cypress. These forests present many of the same problems as the bottomland hardwoods.

The forest land is predominantly in private ownership. A national forest purchase unit, however, has been established in Mississippi. Privately owned lands are made up of both large and small tracts.

Physiographic Features

The southern bottomland hardwood region occupies the flood plains of the major streams of the southern coastal plain and the Mississippi Delta. The topography is characteristically flat, the region terminating in rather abrupt hills adjacent to the flood plains. Although the land surface is relatively flat, there are slight variations in elevation which cause considerable difference in soil and drainage. Two main topographic features, namely, the first bottoms and the second bottoms, are recognized (Putnam and Bull 1932). The former consists of the lower-lying and most recently formed areas of alluvial soil. Originally they were subject to frequent overflow, but protection by levees now

[1] This figure and the acreage figures that follow are taken from the forest survey figures of the Southern Forest Experiment Station, New Orleans, La.

makes inundation uncommon. The second bottoms or terraces, slightly elevated above the first bottoms, are the old flood plains standing above the influence of stream water, except occasionally during severe floods. In addition to these two main topographic features, there are such features as river margins, swags, drains or shallow sloughs, and gullies. Within both the first and second bottoms, the following minor topographic features are recognized: (1) flats, (2) ridges, (3) washboardy and hammocky lands, and (4) swamps. Although the ridges are sometimes several feet high, they are inconspicuous because of the very gentle gradient of the slopes. They are much better drained than the flats, which may be covered by water intermittently during the rainy season. Each of the sites is characterized by a more or less distinctive type of forest.

Practically all the soils are fine-textured. Clays, silt clays, and silt loams predominate. The second bottoms contain, in addition, some fine sandy loams and very fine sandy loams. Along many of the streams, very fine sandy soils are important. All the soils are characteristically high in moisture.

Climatic Features

The climate of the region is characterized by an abundant, well-distributed precipitation, mild temperatures, and a long growing season.

The average annual precipitation in different parts of the region varies from about 43 to approximately 52 inches. The wettest season is from November to April or May, when the average monthly precipitation is between 4 and 5 inches. The driest season is from August to October, when the average precipitation is around 3 inches per month. Snow forms an inconsequential part of the precipitation, several consecutive years sometimes being free of snowfall in some localities. The mean annual snowfall varies from 1.6 to 8.7 inches (Weather Bureau 1926).

The relative humidity of the region is normally high, rarely below 60 per cent. It is somewhat lower in the northern than in the southern part of the region.

The climate is characterized by mild temperatures. The mean temperature for the year varies from 60.2° to 65.6° F. (Weather Bureau 1926). The mean temperature for July, the hottest month of the year, ranges from 80.6° to 82.9° F., and the mean temperature for January, the coldest month, varies from 38.9° to 48.2° F. The length of the growing season ranges from approximately 6½ months in the

northern part of the region to more than 8 months in the southern part.

The winds are chiefly from a southeasterly or southwesterly direction. The average wind velocity is low, although a maximum wind velocity of more than 60 miles per hour has been recorded on several occasions, chiefly along the coast.

Development of Lumbering

Fairly extensive localized cutting occurred in connection with the building up of New Orleans and the southern part of the delta. Extensive cutting in the whole region, however, did not get under way until about 1900. Most of the operations were large, the extensive cutting resulting in a rapid depletion of the old-growth timber. In 1926 the annual cut of timber from Louisiana alone was 790,000,000 board feet (Lentz 1929), or 12 per cent of all the hardwood lumber cut in the United States. The cut for the entire Mississippi Delta was estimated at more than double this amount. By this time many second-growth stands were being cut also. The region is now dependent largely upon second-growth forests for its timber supply.

The Effect of Past Practices

Practically all the cutting has been done without any consideration of the perpetuation of the forest. Where stands have consisted entirely of merchantable timber, the forest has usually been clearcut. In stands containing a considerable amount of trees of low commercial value, culling has been the usual method employed. As a result of these practices, cut-over land is either badly understocked or supports young tree growth of low value (Lentz 1929). Over a considerable area, although in the minority, where conditions have been just right, well-stocked stands of valuable trees have become established.

Fire has done considerable damage to the timber. Very little attention has been given to fire protection in the past, the prevailing idea being that fire was not a serious problem because of the dampness of the sites and the heavy green cover. Fire has been responsible, however, for the extensive infection of trees by various rots, which have greatly reduced their merchantability.

Disposal of slash has been ignored, but this indifference has not created a serious fire-protection problem because slash decomposes very rapidly.

Artificial reforestation has been inconsequential, but it is generally unnecessary except in the absence of seed trees, because the more valuable species usually reproduce well soon after cutting.

THE FORESTS AND THEIR MANAGEMENT

The forests of the southern bottomland hardwood region are diversified. For convenience the major forest types have been grouped into three type-groups, namely: (1) mixed oak–hardwoods, (2) sweetgum–mixed hardwoods, (3) baldcypress. Other forest types of considerable commercial value but not so widely distributed are the cottonwood and swamp tupelo types. Three other types, namely, sugarberry-elm, live oak, and willow are recognized, but they are of minor importance because of low commercial value. These types will not be discussed here.

With the exception of the cottonwood type, about which enough is known to outline specific silvicultural measures, definite recommendations on silvicultural practice will be confined chiefly to the mixed oak–hardwoods types with supplemental suggestions on certain measures for some of the types.

MIXED OAK–HARDWOODS TYPE

Cutting and Planting

Ecological Basis

Character and Composition of Forest. Four distinct forest types are included in this category—mixed oak–hardwoods. Collectively they occupy a large area, and some of them have high commercial value. Table 18 gives detailed data for the individual forest types (Committee Report 1932) that carry different names from those given in an earlier report (Lentz 1931).

Culled stands constitute a large proportion of the acreage of the mixed oak–hardwoods types. Immature second-growth and commercially mature second-growth forests occur here and there in small tracts (Fig. 43).

The virgin forests, now a minor factor in the timber supply, are uneven-aged. Often as much as 25 to 30 per cent of the stand volume is unmerchantable.

TABLE 18

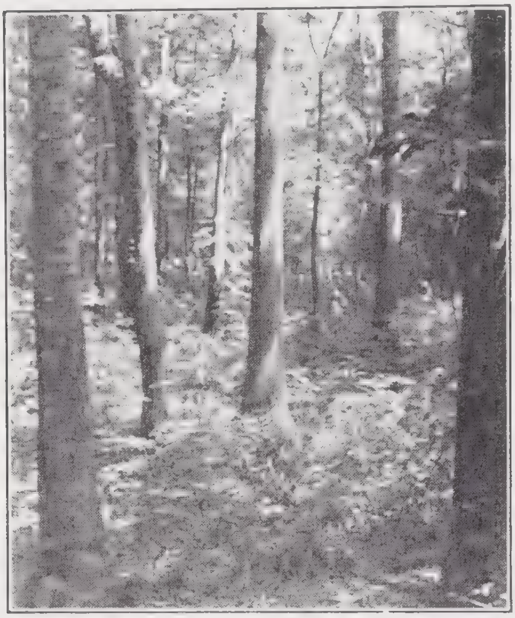
Description of Mixed Oak–Hardwoods Types

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Hickory–swamp chestnut oak–white oak (numerous subtypes can be recognized)	Minor	High	Mostly on loamy ridges and hammocky ground, but occasionally on loamy flats of second bottoms	Swamp chestnut oak and white oak, but sometimes replaced by post oak (swamp). Two or three of the following hickories: Shagbark, shellbark, pignut, mockernut, nutmeg, bitternut	Nuttall oak Water oak Sweetgum American elm Green ash White ash Winged elm Black tupelo	Unknown
Willow oak	Moderate	Moderate	Undulating or washboardy parts of first bottoms in Mississippi Delta; elsewhere poorly drained flats, mostly in second bottoms	Willow oak Swamp red oak Swamp chestnut oak Nuttall oak Winged elm White ash Green ash	Overcup oak American elm Water oak Cedar elm	If cut heavily, succeeded by oak-elm-ash type
Oak-elm-ash	Moderate	Moderate	Chiefly poorly drained flats of alluvial flood plain, but also any cut-over area	Varies with site. In second bottoms, winged elm and white ash. In first bottoms, willow oak, water oak, overcup oak, Nuttall oak, swamp red oak	Many, varying greatly with site	Usually a residual type, following cutting in sweetgum–Nuttall oak–willow oak type or in the willow oak type
Overcup oak–water hickory *	Moderate	Low	Poorly drained clay flats in first bottoms (especially in La. and Miss.) and poorly drained depressions, sloughs, and shallow swamps in second bottoms	Overcup oak Green ash Willow oak Persimmon Nuttall oak American elm Red maple Water hickory	Baldcypress Sweetgum Water oak Cedar elm	Climax type

* Locally known as bitter pecan.

Stand Regeneration and Development. Advance reproduction is generally sparse in the denser stands, excessive competition probably being the most significant factor in the deficiency.

Definite facts concerning the regeneration of the mixed oak–hardwoods types are lacking. The following generalizations are based chiefly on observational studies. Sprouting is a minor factor in regeneration after cutting in any stand.



Photograph by U. S. Forest Service.

Fig. 43. In well-stocked second-growth oak–mixed hardwoods stands, natural pruning is sufficiently good to produce trees that have the potentialities of high quality.

The elms and ashes have an advantage over the oaks in regeneration, because they are more prolific seeders, their seed is disseminated farther and consumed less by rodents, and they are less exacting in seedbed requirements. However, after good seed years the oaks reproduce in considerable quantity if the site is partially protected by a canopy.

Growth and tolerance differences of the various species in the stand are not sufficiently great to have any material effect in the struggle for supremacy in young stands. A moderately open site is essential to satisfactory growth of all species.

Windfall. Because root development is deep, windfall is of minor consequence. Windbreakage, associated with severe heart rot, is not uncommon in mature trees.

Windshake is a common defect in the oaks, particularly the overcup oak. Trees so affected yield low-quality lumber.

Economic Basis

Many of the statements in this section apply to the sweetgum–mixed hardwoods and the southern cypress types also. Many of the species occur in all types and, although the timber they produce differs in quality in the various forest types, nevertheless, the general statements

made here regarding utilization are almost equally applicable to all types.

Utilization and Marketing Problems. *Products in Demand.* Existing markets for timber products are not diversified. High-quality lumber is the chief product that can be marketed profitably throughout the region. In some sections fuelwood and posts are in demand, thus providing an outlet for low-grade material but one too localized to be broadly significant. Increased utilization of southern hardwoods for box boards and structural timber must develop before extensive use can be made of low-grade, sound material. The development of a market for cooperage stock is needed as an outlet for high-grade material that is too small for saw logs.

The wood of several species is well suited for small dimension stock and veneer, but little material is now employed for these purposes. Cottonwood, black willow, boxelder, southern magnolia, red and silver maple, sweetgum, and water tupelo, used for pulpwood wherever paper mills employ the soda process, should be employed more extensively in the future for pulpwood.

Relative Value of Species. Table 19 indicates the relative value of the individual southern hardwoods for commercial use (Staff of the Southern Forest Experiment Station 1933). Three species—cottonwood, Nuttall oak, and willow oak—originally classified as group 2 species have been assigned by the author to group 1, in the light of Bull's study (1945).

Marginal Tree. Although there are no data to substantiate the following statement, it appears, because of the great diversity in quality of different species, that the size of the marginal tree varies widely with different species. For sweetgum, a species that consistently yields high-quality lumber, the better grades of lumber are produced by trees over 18 to 20 inches d.b.h. For most species, trees under 24 inches d.b.h. seldom yield high-quality lumber (Putnam and Bull 1932). Trees of excessive knottiness and therefore of little value for lumber can sometimes be utilized to small diameters for railroad ties.

The marginal tree of pulpwood species is probably around 10 inches d.b.h.

Growth and Rotation. In a study of growth in an unmanaged stand, Bull (1945) found that twelve different species grew an average of 1.0 to 3.3 inches in 10 years. On the basis of these data he estimates that mature dominant crop trees in a well-stocked managed stand

should grow 2.0 to 4.0 inches in diameter in 10 years. Considering rate of growth, quality of timber, and market value, Bull rates the following species as the most valuable: Nuttall oak, willow oak, cottonwood, green ash, and sweetgum.

Saw logs can be produced in 60 to 80 years.

TABLE 19

TREE SPECIES COMMONLY FOUND IN THE SOUTHERN HARDWOOD FORESTS LISTED IN ORDER OF RELATIVE DESIRABILITY

Location	Group 1, To Be Definitely Favored If of Good Quality and Thrift	Group 2, To Be Tolerated If of Good Quality	Group 3, To Be Discriminated against Unless Particularly Good	Group 4, To Be Removed Always If Competing with Desirable Trees
Delta and principal alluvial bottoms	Ashes Baldcypress Cottonwood Bur oak Swamp chestnut oak Post oak White oak Sweetgum Shumard oak Swamp red oak Nuttall oak Willow oak	Sugarberry American elm Water tupelo Hickories Silver maple Pecan Willow Persimmon Mulberry American sycamore Pin oak Water oak	Overcup oak Black tupelo Cedar elm Honeylocust Red maple Live oak Water hickory	Hawthorn Swamp cyrilla Hercules club Swamp privet Planertree
Bottom of secondary streams, coves, etc.	Ashes Bur oak Swamp chestnut oak Post oak White oak Yellow-poplar Loblolly pine Black walnut Sweetgum Shumard oak Swamp red oak Southern magnolia Baldcypress Willow oak	Hickories Pin oak Slash pine Water oak American elm American basswood American holly Bays Mulberry Black locust	Black tupelo American beech Laurel oak Red maple River birch	

APPLICATION OF METHODS

Selection Cutting. Although reports on results of cutting methods that seem practicable are meager, it appears that selection cutting of mature mixed oak–hardwood forests proves effective in regenerating the forest and in meeting the market situation. A reasonably satisfactory reserve stand will be left by cutting roughly to a diameter limit of 22 to 24 inches.

Careful consideration should be given to species selection in order that the future stand may be composed of the maximum number of valuable trees. Group 1 trees of good quality and thrift should be favored. Group 2 species of good quality may be retained but should not be favored. Individual group 3 species of exceptionally good quality can be retained when they are not interfering with group 1 and group 2 species; otherwise, they should be cut, girdled, or poisoned. The water oaks, the elms, hackberry, and red maple should be cut closely because they regenerate so prolifically. Group 4 species should always be disposed of.

Generally, it is unnecessary to favor seed trees, because the reserve stand ordinarily contains an adequate number of them. Parts of stands, because of the preponderance of large trees, have to be cut so heavily that the retention of occasional seed trees is necessary.

Stand Improvement. Stand-improvement work in the form of liberation cutting and cleaning is essential on newly as well as old cut-over lands. In newly cut-over stands girdling or poisoning of the undesirable trees of the residual stand should be done soon after selection cutting is completed. Cleaning should be postponed until differentiation in the height and development of the reproduction has occurred—usually 2 to 4 years after the reproduction cutting.

Old cut-over land must be treated in accordance with its condition, as follows (Staff of the Southern Forest Experiment Station 1933):

1. Stands with a sparse overstory and sparse reproduction—No treatment.

2. Stands with a dense overstory (usually of low value) and sparse understory—Girdle or poison only those trees in the overstory that are actually suppressing desirable reproduction.

3. Stands with a sparse overstory and dense understory (typical of most of the older cut-over areas)—Girdle or poison all trees in the overstory except well-formed trees of desirable species (if there are any), and clean or thin the understory.

Thinning. Thinning can be done advantageously in second-growth stands, particularly those on old fields, since they are generally very dense. Thinning, preferably of the crown type, should be made only after the better trees are well pruned. The degree of thinning must be based on present or prospective market conditions and stand composition. Stands containing few pulpwood species or located where pulpwood cannot be utilized should be thinned fairly heavily, so that not more than two thinnings will be needed during the rotation. Where

the stands are managed primarily for saw timber, the thinning should be lighter and more frequent. In stands containing trees of the average diameter indicated, the thinning should aim to retain the following stand density: 4 inches, 430 trees per acre; 6 inches, 300 trees per acre; 8 inches, 200 trees per acre; 12 inches, 120 trees per acre (Staff of the Southern Forest Experiment Station 1933).

Planting. Artificial regeneration by planting can be done advantageously on old cut-over lands that support either or both a reproduction and residual stand of inferior species and on abandoned farm land not accessible to a natural source of seed. Sweetgum, the better oaks, white and green ash, and red mulberry are well suited to mixed oak–hardwoods sites. One-year-old seedlings, spaced 10 by 10 feet, are recommended.

Miscellaneous Silvicultural Problems

The disposal of logging slash is generally unnecessary because the damp sites keep the inflammability of the slash low and cause such rapid decomposition that, after 2 years, slash is no longer a serious hazard. In drought years or on areas of unusually high fire hazard, either partial disposal of the slash by piling and burning or special protection may be advisable.

Rot caused by several different fungi, entering in most cases through fire wounds, is widespread. It is the cause of much serious loss as evidenced by a 14 per cent loss of merchantable wood volume in a 70-year-old oak stand damaged by fire 20 years previously (Kaufert 1933). Windbreakage of these defective trees is not serious since it is most common among the poorer trees (overtopped and intermediate crown classes) (Hepting 1935).

Fire prevention is the key to the control of diseases. Badly decayed, unmerchantable trees can be disposed of most economically by girdling or poisoning.

Insects, particularly ants and termites, are often associated with the decayed wood, but they play a minor role in the ultimate damage. Other insect pests are of minor consequence in the mixed oak–hardwoods types.

Although grazing of forest lands by domestic livestock causes a certain amount of damage, some authorities believe that light grazing during the first one-third to one-half of the cutting cycle is feasible. Indiscriminate or continuous grazing cannot be allowed.

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SWEETGUM–MIXED HARDWOODS TYPES

Cutting and Planting

Ecological Basis

Character and Composition of Forest. Three distinct forest types, each described in detail in Table 20, are recognized in the sweetgum–mixed hardwoods type-group.

TABLE 20

Description of Sweetgum–Mixed Hardwoods Types

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Sweetgum–swamp red oak	Major	Moderate to high	High flats and ridges, fairly well drained, and seldom covered with standing water	Sweetgum Swamp red oak Swamp chestnut oak Water oak Various ashes Post oak Hickories Black tupelo	Honey locust Willow oak Shumard oak American elm Winged elm	Unknown
Sweetgum	Secondary	High	High flats or low ridges that are not overflowed annually, and old fields	Sweetgum (sometimes pure) Water oak Nuttall oak American elm Willow oak Hackberry Green ash White ash	Many and varied	Unknown
Sweetgum–Nuttall oak–willow oak	Secondary	Moderate	Low silty clay flats, often covered by water in winter	Sweetgum Nuttall oak Willow oak	Overcup oak Water oak American elm Green ash Pin oak	Unknown

Second-growth stands are usually even-aged and well stocked. Culled stands, composed chiefly of limby trees of any species, and all types of trees of low-value species occupy extensive areas. Virgin forests are in the minority.

Stand Regeneration and Development. Advance reproduction in virgin stands is sparse and irregular, being concentrated in the larger openings of the forest.

Sprouts do not form an appreciable part of the reproduction following cutting of stands over 50 years old.

Sweetgum usually reproduces rather well. It produces fairly good seed crops nearly every year and heavy seed crops about every third year (Chittenden and Hatt 1906). Abundant moisture and an open site are the chief requisites to a good stand of sweetgum seedlings. Just how open the site must be for abundant reproduction is not known. A heavy sod or herbaceous cover is inimical to sweetgum seedling establishment. Although intolerant, sweetgum seedlings meet competition with seedlings of other species satisfactorily because their rapid growth soon places them in a dominant position.

Of the major species of the sweetgum–mixed hardwoods types, American elm and the ashes are the best reproducers; a limited number of seed-bearing trees of these species provide for abundant reproduction. Established seedlings of these species are not easily suppressed because their growth is rapid. They are likely to be the chief competitors of sweetgum. However, when cottonwood is present in the reproduction, this species is the first to gain a dominant position, but when crowded it usually drops out after 30 to 40 years.

The oaks are subject to the same handicaps as in the mixed oak–hardwoods types.

Windfall is uncommon because the trees have well-developed root systems. Neither is windbreakage a matter of consequence.

Economic Basis

The economic facts for the mixed oak–hardwoods types, presented on p. 253, are, in large part, applicable to the sweetgum–mixed hardwoods types.

The data that follow, taken from a single stand in Louisiana, are merely suggestive of growth possibilities. Net annual growth per acre of 175 board feet on a reserve stand of 6719 board feet in this case is regarded low because of high mortality due to drought (Davis 1935). With the exception of one or two species, growth after cutting was much faster than before, especially for some of the oaks, particularly cherrybark and Nuttall oak.

Of particular significance from the utilization standpoint is the fact that 74 per cent of the volume of the trees 28 inches d.b.h. and larger was composed of high-quality logs (grades 1 and 2), whereas only

44 per cent of the volume of the trees under 28 inches d.b.h. was composed of logs of similar quality. This fact emphasizes the importance of producing reasonably large trees.

Photograph by U. S. Forest Service.

FIG. 44. A stand of the sweetgum–mixed hardwoods type that has been handled by selection cutting for 40 years, the most recent cutting having occurred 3 years previously. By selection cutting only the trees that produce high-quality logs are removed.

APPLICATION OF METHODS

Cutting methods and planting should follow the same general plan as outlined for mixed oak–hardwoods types (Fig. 44).

Disease and insect control and slash disposal present the same problems and should be handled in the same way as outlined for the mixed oak–hardwoods types also (p. 256).

COTTONWOOD TYPE

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of Forest

Importance.

Area—Minor.

Commercial Value—High.

Sites Occupied—Sandy or silty soils of river bottoms, chiefly on batture lands (lands between the levee and river) and old fields.

Associated Species (Fig. 45).

Major—Cottonwood, often pure, black willow.

Minor—Boxelder, hackberry, American sycamore, sweetgum, green ash, American elm, silver maple, red maple.

Place in Succession—A temporary type on overflowed sand bars and flats in batture land.

Photograph by U. S. Forest Service.

FIG. 45. A very open virgin stand of cottonwood. Some hackberry, boxelder, and silver maple are in mixture. The cottonwood is large, and its bole is clear to considerable height.

Cottonwood stands are nearly always even-aged. Mature stands are open and produce from 4000 to 12,000 board feet per acre. Forests in almost any stage of development from seedling to maturity are scattered through the region.

Stand Regeneration and Development. Advance reproduction, usually scarce, is composed chiefly of red maple, American elm, boxelder, American sycamore, and sugarberry.

Vigorous cottonwood sprouts come chiefly from trees cut before they reach 30 years of age. Little or no sprouting can be expected from trees over 45 years old. Cottonwood sprouts, to develop into trees, must grow close to the ground (possible only when stumps are not

over 6 inches high), because rapid rotting of the stump otherwise causes them soon to break off. Sprouts free of competing vegetation grow very rapidly.

Although cottonwood is a heavy seed producer, it often fails to reproduce naturally from seed because the seed, which loses its viability within a few weeks after maturity, frequently falls on an unsuitable seed bed. An abundance of moisture and exposure of the mineral soil are requisites to a high percentage of germination. Cottonwood seedlings, like cottonwood sprouts, are intolerant, and they must, therefore, be reasonably free from competition of established underbrush and residual trees if they are to survive. Since the cottonwood type is temporary, other species, such as green ash, boxelder, red maple, sycamore, and sweetgum, tend to replace it unless it reproduces generously from seed, which it rarely does. The cottonwood has an advantage in rate of height growth, but this is of no practical significance if the tree is not well represented in the stand. Maintenance of the cottonwood type is therefore difficult.

Windfall. Cottonwood develops a reasonably deep root system, which, except on poorly drained sites, gives ample anchorage to make it windfirm.

The wood of cottonwood is soft and brittle, making the tree very susceptible to windbreakage.

Economic Basis

For general use cottonwood is the most valuable species of the cottonwood type. The most complete utilization can be made where it can be marketed for pulpwood, for which purpose trees as small as 10 inches d.b.h. can probably be handled economically. Useful also for pulpwood in some localities, but less valuable, are black willow, boxelder, and silver maple.

A rotation of more than 50 to 60 years is inadvisable, because deterioration of the wood from decay is rapid in older stands.

Planting, although more expensive than natural reproduction, apparently must be resorted to on the driest sites. On a 35-year rotation, net return per acre per year based on 4 per cent carrying costs has been calculated to be $1.99 for land protected by levee and $3.77 for unprotected batture land (Bull and Muntz 1943).

Application of Methods

It is difficult to maintain the cottonwood type by any system of natural regeneration. It is recognized that it generally is not easy

to maintain the representation of cottonwood by the methods suggested below; but, so far as present knowledge goes, other methods are probably no more effective, and the suggested methods do have certain economic advantages.

Clearcutting and Seed-Tree Cutting. On sites having high moisture content, clearcutting or seed-tree cutting is suggested to reproduce stands over 45 years old. On dry sites, planting, described below, is probably superior. Clearcut strips should be not more than 600 feet wide.

With the seed-tree method seed trees should be left at a rate of at least one per acre. Approximately every fourth tree should be a *male tree* (Williamson 1913). Often trees that would yield inferior products can be retained for seed if they are thrifty and windfirm. Soil treatment, described below, is probably needed on many sites to prepare the seed bed. Seed trees should be either cut or girdled, as circumstances dictate, after reproduction is established; otherwise, they will interfere with the growth of the new stand.

If managed chiefly for pulpwood, cottonwood stands under 40 years old, and particularly those under 30 years, can be reproduced fairly effectively by the coppice method. Stumps must be cut low—not over 6 inches high—in winter or early spring.

Soil Treatment. Treatment of soil and vegetation of many sites is apparently essential to insure establishment of a reproduction stand (Williamson 1913). Soil treatment is necessary only when logging does not break up the litter and expose the mineral soil adequately. Harrowing is desirable where the litter is very thick. Vegetation should be cut shortly before seed dissemination.

Thinning. Thinning must be applied to dense second-growth stands. One moderately heavy thinning, made when the trees are large enough for pulpwood (where a market exists), should be ample in stands managed primarily for pulpwood.

Planting. Planting sites should be properly prepared. This can best be done by burning or disking. The plowing of furrows is also highly desirable. One- or two-year seedlings or cuttings taken from the tops of such seedlings are satisfactory. Seedling tops should be cut back to 10 inches; cuttings should be 20 inches long (Bull and Muntz 1943). Trees or cuttings should be spaced 6 feet apart in rows 10 feet apart. Planting should be done between late November or early December and early or late March.

Cultivation or release during the first year has been described as a necessity to satisfactory survival of cottonwood (Bull and Muntz

1943). Later work has demonstrated that fertilization of each tree with 2 ounces of ammonium nitrate may be superior to and less expensive than cultivation or release.

Miscellaneous Silvicultural Problems

The slash hazard is short-lived since cottonwood slash is very perishable, reaching an advanced stage of decay in 2 or 3 years, and since the slash of other species is only slightly more resistant to decay. This, together with the fact that slash apparently has little effect on regeneration, is sufficient reason for recommending that slash be left untreated.

Fomes applanatus, causing a white rot in both sapwood and heartwood, occurs chiefly in trees wounded mechanically or by fire (Williamson 1913). It is responsible for the loss of considerable merchantable material and for windbreakage. Other diseases and insects are unimportant.

Prevention of mechanical injury to trees during cutting and logging and fire prevention are the keys to disease and insect control.

Since young cottonwood reproduction, because of its succulency, is relished by domestic livestock and rodents, grazing animals should be barred from reproduction stands and rodents should be adequately controlled.

BALDCYPRESS TYPES

The two types, baldcypress and baldcypress-hardwood, that compose this type-group are described in Table 21 (Committee Report 1932).

Little of the virgin baldcypress forests remain. Heavy cutting of the baldcypress-hardwood forests has all but obliterated this type, most of it having reverted to a sweetgum or a sweetgum–Nuttall oak–willow oak type. The remaining virgin baldcypress forests are uneven-aged and fairly dense. Average stands contain 8000 to 10,000 board feet per acre (Fig. 46).

Culled forests, most of them in a very unproductive condition, constitute the bulk of the area occupied by the baldcypress types. Close cutting of the cypress has given it little opportunity to reproduce. Reproduction in these culled stands has come chiefly from the residual stand of inferior hardwoods

Fire, submergence by water, and stream deposition account for the scarcity and irregular distribution of advance reproduction in the majority of baldcypress forests (Mattoon 1915). Sprouting is not a

reliable means of regeneration. Regeneration from seed is beset with difficulties in spite of generous seed crops about every 3 years and the production of some seed nearly every year. Abundant germination of seed depends on a saturated soil for a period of 1 to 3 months (Mattoon 1915). Adequate seed for a well-stocked stand apparently is provided by four to eight trees per acre between 10 and 18 inches d.b.h.

TABLE 21

DESCRIPTION OF THE BALDCYPRESS TYPES

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Baldcypress	Major	High	Sloughs, bayou margins, deep swamps, and river bottoms that are wet for extended periods	Baldcypress (sometimes pure) Water tupelo	Red maple Planertree Water oak Swamp tupelo	Climax type. May revert to water tupelo type after cutting
Baldcypress-hardwood	Secondary	Moderate	Clay or silty clay loams of alluvial flood plains where water frequently stands	Baldcypress Green ash Sweetgum Red maple Silver maple	Overcup oak Nuttall oak American elm Pin oak Hackberry Water hickory	Climax type

Although cypress seedlings make their best growth on open sites, they are sufficiently tolerant to make good growth under a partial canopy. Growth in the open to a height of 14 to 20 inches in 2 years and 4 to 6 feet in 4 years gives southern cypress seedlings an advantage over seedlings of their associates.

Red maple and water tupelo are such prolific seed producers and their seed has such a high percentage of germination that they are likely to be well represented in the reproduction even when they are cut closely. Because of their rapid growth, seedlings of these species offer baldcypress seedlings their chief competition.

The baldcypress, as well as its hardwood associates, develops strong root systems that make the trees windfirm.

Insufficient data are available to attempt a discussion of the economics of cutting and planting practices for the baldcypress types.

Reference should be made to the general discussion under the mixed oak–hardwoods types (p. 253). For information on the application of cutting methods, again reference should be made to the mixed oak–hardwoods types.

Baldcypress slash is more resistant to decay than hardwood slash, but since the sites are the wettest of the region it seldom becomes inflammable. Therefore, slash need not be disposed of.

Photograph by U. S. Forest Service.

Fig. 46. A typical virgin stand of baldcypress with a few hardwoods in mixture.

A heart rot caused by *Fomes geotropus* and referred to as "pecky cypress" is fairly common. Presumably it is associated with wind or other mechanical damage. Numerous hardwoods are defective, the result of rot that has entered fire wounds.

Protection from mechanical and fire injury solves in large part the defect problems.

WATER TUPELO TYPE

Facts concerning the management of the water tupelo type are extremely meager. Nevertheless, attention is herewith called to the existence of this type because of its widespread occurrence in the same general territory as the baldcypress types with which it is intermingled. The water tupelo type on many sites is the result of

cutting a cypress type in which the water tupelo was not cut when the forest was exploited (Committee Report 1932). Since the stands are frequently of second quality, they have low commercial value.

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8 · *Central Hardwood Region*

DESCRIPTION AND HISTORY

Location and Landownership

The central hardwood region occupies an extensive area of diverse forest in the central United States, including all of Ohio, Indiana, Illinois, Iowa, and Missouri, southern Michigan, Wisconsin, and Minnesota, the eastern part of Nebraska and Kansas, the northeastern part of Oklahoma, northern Arkansas, and western Kentucky (Fig. 1). Because of the differences in the character of timber, past treatment of the lands, and landownership, three distinct divisions of the region are recognized, namely: the corn belt, the uplands of the lower Ohio basin, and the Ozarks. In the corn belt the bulk of the land is devoted to agriculture, with small farm woodlands, the characteristic type of forest, comprising 10 per cent of the land area. Elsewhere forested areas are more extensive, comprising 40 to 50 per cent of the land area of the lower Ohio basin and 70 per cent of the Ozarks. In addition to the 55,000,000 acres of land supporting forest, there is an estimated 15,000,000 acres of submarginal and abandoned land that should be restored to forest. In spite of farm abandonment, the forest-land area in the corn belt is steadily decreasing (Day 1934). Approximately 2,600,000 acres of forest are in national forests (as of December 1947). The states own in the aggregate only about 500,000 acres, chiefly in Ohio, Indiana, and Missouri.

Physiographic Features

The physiography is diversified. Most of the corn belt has a relatively flat surface, broken, however, by local sections of undulating hills and sharp breaking valleys. The western part of the corn belt is made up chiefly of prairie soils, which are characterized by a dark color, indicative of high humus content. Silt loams and silts are the

predominant soils. Most of this section lies at an altitude of 600 to 800 feet. The southern boundary of the corn belt marks approximately the southern limit of glaciation.

The Ozarks and uplands of the lower Ohio basin are very hilly, the altitude ranging chiefly between 1000 and 2000 feet, with a few points reaching an altitude of 2500 feet. These sections belong to the province of gray and brown forest soils. Silt loams, sandy loams, clay loams, and loams are typical of the southern part of the region. The Ozark soils are comparatively low in organic matter, relatively dry because of their structure, and many of them are stony.

Especially along the Ohio, Missouri, and Mississippi Rivers, and to a lesser degree along the smaller water courses, there are large areas of bottomland soils, generally poorly drained.

The principal water courses drain into the Ohio, Missouri, and Mississippi Rivers.

Climatic Features

The wide range in latitude and longitude causes a diversity of climate. Most of the corn belt has an average annual precipitation of 30 to 40 inches (Weather Bureau 1926). The western part of the region, which merges into the prairies, has much less precipitation, a total of only 20 inches annually in some sections. In the extreme south it amounts to 40 to 50 inches annually. In general, precipitation is heaviest during the late spring and early summer. In the north half, a large portion of the winter precipitation is in the form of snow. The southern half has very little snowfall. Except in the extreme northern part of the region snow seldom remains on the ground for extended periods.

The relative humidity is generally in excess of 60 per cent but occasionally drops to 40 or 50 per cent.

The mean annual temperature varies from 46° F. in the northern parts to 56° F. in the southern parts of the region. Summer temperatures are generally rather high. High temperatures are particularly characteristic of the western and southern parts of the region, where a temperature over 100° F. is fairly frequent. The mean temperature for July is from 67° to 79° F. The mean temperature for January, the coldest month, ranges from 19° to 31° F. in the southern part. The growing season varies from 5 to 7 months.

Thunderstorms are nearly always accompanied by moderate to heavy precipitation and, therefore, are not an important source of fire danger.

The prevailing winds for most of the region during summer are from the south or southwest; in winter they are generally from the northwest. The average wind velocity is moderate. Maximum wind velocities of from 45 to 50 miles per hour have been recorded at many stations (Weather Bureau 1926). Tornadoes occur in some part of the region every year.

Development of Lumbering

The first commercial timber operations in the central hardwood region began early in the nineteenth century. Along with the cutting of timber for industry much wood was cut and the logs burned to clear a large area for agriculture. In some sections the trees were girdled and then left standing. In the latter part of the nineteenth century the central hardwood region was making a considerable contribution to the nation's lumber production. Early in the twentieth century production was declining, owing to decreased availability of supplies. Whereas the cut of lumber in 1899 was approximately 5,500,000,000 board feet, in 1910 it had declined to 3,500,000,000 board feet and, in 1934, to approximately 750,000,000 board feet. Lumber consumption, on the other hand, was approximately 3,500,000,000 board feet in 1934.

Moderately large operations supplemented by numerous small ones characterized the development in the Ozark and Ohio uplands sections. In the corn belt small operations predominated. Small sawmills are becoming increasingly important in the entire region (Day 1934). Wood-using industries have disappeared to such an extent in many of the agricultural sections that woodland owners have some difficulty in marketing their timber advantageously.

Effect of Past Practices

Except where clearcutting for charcoal stock was applied, culling of the forest has been common practice. The early cutting for black walnut, white ash, and yellow-poplar left the forests well stocked, but when a larger number of species became marketable the stand after cutting became sparse and retained chiefly low-value trees. Defective and misshapen trees and low-value species took possession of the site. These trees naturally increased their representation through regeneration. As long as grazing and fire were under control, trees occupied the site rather completely. Intensive grazing in the corn-belt wood-

lands has destroyed much of the desirable reproduction, compacted the soil, destroyed the humus, and injured the roots of the older trees. In most of the farm woodlands heavy cutting, combined with the grazing, has caused the formation of a heavy grass sod that has seriously impaired the establishment of tree seedlings (Day and Den Uyl 1932). In Indiana, where a comprehensive study of the effects of grazing has been made, grazed forests have been classified into four categories: early, transition, open park, and final (see p. 272 for description of these stages). Although grazing has not been so concentrated in the unglaciated sections, extensive damage has resulted from overgrazing.

Annual burning has been common practice in the forests of the Ozarks and even somewhat farther north. In consequence, the trees are defective, seedling reproduction is sparse, and the soil is depleted of its humus and thus its water-absorptive capacity is reduced.

In certain parts of Missouri and Ohio, many of the early operations took the form of clearcutting for supplying the raw material for charcoal. Even-aged stands, composed of coppice reproduction supplemented by small amounts of seedling reproduction, developed after such treatment. In the southern part of the region, where one or more of the three native pines constitutes a large part of certain stands, the usual type of cutting, which cut the pine to a low diameter, thus leaving few, if any, seed-bearing trees, has favored the hardwoods in regeneration.

Slash disposal was seldom practiced. The lack of slash disposal in farm woodlands was relatively unimportant, because after the close utilization that was generally practiced on these areas only a light cover of slash was left. In the larger timberland areas utilization at the time of cutting the virgin forests was rather crude. The heavy accumulations of slash so increased the fire hazard on some of these lands that a number of bad fires resulted. This situation seldom exists now, because few stands support a heavy volume.

Extensive forest planting in the form of shelterbelts, windbreaks, fence rows, and small block plantations for protection and shade was done during the period 1860 to 1890 chiefly by farmers, particularly in the prairie sections. Then followed a period of limited planting, to be succeeded in recent years by increased planting, both by farm owners and by the State and Federal Governments, chiefly for erosion control and the utilization of poor-quality land, and, to a lesser degree, for the improvement of deteriorated stands.

THE FORESTS AND THEIR MANAGEMENT

The great variety of climate and soils over the wide range in latitude and longitude is responsible for the great diversity of forest cover in the central hardwood region. Four broad forest associations, each represented by a few to several distinct forest types, can be recognized. These are the oak, beech–sugar maple, shortleaf pine–oak, and bottomland forests. The oak types, numbering eight, are the most widely distributed and occupy the largest area, approximately 35,000,000 acres.

In the southeastern part of the region there are about 3,000,000 acres of oak forest—not included here with the oak type—that formerly contained a considerable amount of yellow-poplar. The beech–sugar maple types, occupying about 4,000,000 acres, are most extensive in the northeastern part of the region but are important also in the Mississippi River bottoms. The shortleaf pine–oak types are most extensive in southern Missouri and northern Arkansas where they occupy about 8,000,000 acres. Scattered through the oak and shortleaf pine–oak types is an undetermined area of small to relatively large tracts of the eastern redcedar type. The bottomland types constitute 6,000,000 acres along streams and in swamps.

The bottomland types, in character and the problems that they present, are so similar to these types in other regions that they will not be discussed in detail here. The black ash–American elm–red maple type, found chiefly in the northern part of the region, presents the same conditions as this type in the oak region (p. 107). The stands have been culled lightly for the small amount of the more valuable trees.

The cottonwood and willow types occur chiefly on the lowlands adjacent to the Ohio and Missouri Rivers. Reference should be made to the southern bottomland hardwood region for a discussion of these types (see p. 259).

OAK TYPES

Cutting and Planting

Ecological Basis

Composition and Character of the Forest. Of the eight oak types occurring in the central hardwood region, only one, the bur oak type, is found in this region alone. Four types, namely, the scarlet oak–black oak, white oak–black oak–northern red oak, the white oak, and

the northern red oak–basswood–white ash, are important forest types of the oak region, to which the reader is referred for more detailed descriptions (p. 85). The post oak–blackjack oak and black oak–post oak types are important forests of the southern Appalachian region, to which the reader is referred for more detailed descriptions (p. 165). The white oak–black oak–hickory type, a newly described type, is the most important oak type in the Ozarks (Kuenzel and Averell 1935). Types are described in Table 22.

Although blackjack oak is strongly represented in some of the oak types, its slower growth and higher mortality than that of the better species puts it at a disadvantage in maintaining itself. It appears that in stands in which desirable species are represented by ninety or more trees per acre, these species survive in sufficient number to constitute an adequate stocking at maturity (Liming 1942).

The oak forests are chiefly of three kinds: (1) even-aged second growth, lightly to moderately stocked with trees chiefly of sprout origin, low-value species and defective stems often predominating; (2) open, culled old growth (even- or uneven-aged) made up chiefly of reasonably sound low-value species and defective trees of high-value species; and (3) uneven-aged well-stocked stands composed chiefly of valuable trees. The latter type of forest is distinctly in the minority. Virgin forests are rare.

In the corn belt grazed forests fall into four categories. Each represents a different problem in management. Den Uyl, Diller, and Day (1938) describe these stages as follows:

1. Early stage—Trees under 4 to 6 inches in diameter, and all but the least palatable shrubby growth absent.

2. Transition stage—Ground cover dominated by weeds that gradually give way to blue grass. Trees in the lower crown classes absent, crown canopy open, and tree reproduction scarce.

3. Open park stage—Blue grass sod established; crown density 50 to 70 per cent; all but the most unpalatable tree seedlings absent; occasional old trees are stagheaded.

4. Final stage—Tight cover of blue grass sod; crown density under 50 per cent; tree reproduction completely absent; stagheaded old trees numerous.

A study of the condition of second-growth oak stands in southern Missouri revealed that 68 per cent of the trees with fire scars or branch stubs over 2 inches in diameter were defective, accounting for a loss of 31.6 per cent of the board-foot volume in trees over 9.6 inches

TABLE 22

DESCRIPTION OF OAK TYPES

Forest Type	Importance: Area	Importance: Commercial Value	Sites Occupied	Associated Species: Major	Associated Species: Minor	Place in Succession
Black oak–post oak	Minor	Low	Relatively dry south slopes in south-central Illinois, Missouri, and Arkansas Ozarks	See p. 165		
Scarlet oak–black oak	Major	Low to moderate	Hill regions of southern Illinois, Indiana, Ohio, and southeastern Missouri on dry sites	See p. 85		
White oak–black oak–northern red oak	Major	High to moderate	Entire region on loamy well-drained soils	See p. 85		Semipermanent, with sugar maple increasing (Committee Report 1932)
White oak	Minor	High	Well-drained loam of Ozark region	See p. 85		
Northern red oak–basswood–white ash	Minor	High	Northern part of region on fertile well-drained soils, particularly on north slopes in eastern Nebraska and central Iowa	See p. 85		
Post oak–blackjack oak	Major	Low	Throughout southern part of region on driest sites	See p. 165		
Bur oak	Minor	Moderate	Western part of region chiefly on black prairie loam, well drained to dry. Also Minnesota on dry exposed sandy plains and south and west loamy slopes.	Bur oak Northern pin oak Northern red oak White oak Black oak	American basswood American elm	Pioneer type on edge of prairie, succeeded by northern pin or white oak–red oak type (Committee Report 1932)
White oak–black oak–hickory	Major	High to moderate	A variety of soils on ridge tops, benches, and lower slopes throughout the Ozarks and in unglaciated parts of southern Indiana	White oak Black oak Hickories	Sweetgum Red maple Chinquapin Winged elm Flowering dogwood Sassafras Black tupelo	The original climax forest (Kuenzel and Averell 1935)

d.b.h.[1] In an Iowa study, 60 per cent of the trees in oak-hickory forests were partially defective, but only 85 per cent of the merchantable volume of trees 9.6 inches d.b.h. and larger was lost because of defect (Genaux and Kuenzel 1939). Loss of wood volume from defect was less in smaller trees. Persistent dead limbs characterize the trees in understocked stands.

A considerable acreage of oak forest land that has been cleared for agriculture and subsequently abandoned is represented by a variety of conditions. Areas abandoned only a few years may still be eroding or may support a scattering stand of persimmon and sassafras; areas abandoned several years usually maintain a moderately to well-stocked stand of these species; areas abandoned more than 10 years support a scattered reproduction stand of high-value species underneath a moderately to well-stocked overstory of persimmon and sassafras.

Stand Regeneration and Development. Regeneration of the severely deteriorated even-aged second-growth and open, culled old-growth stands is vital to the rehabilitation of these forests, since no improvement is possible without reproduction (Fig. 48). Except in small localized groups, cutting can be of little help in improving conditions for reproduction. Fire protection and grazing control are the first steps toward improvement of these stands. Oak forests that have been managed by selection cutting and have had adequate protection from fire and grazing usually reproduce fairly well (Fig. 47).

However, except in those few stands that have been well managed for an extended period, reproduction is sparse or lacking. In the corn belt the deficiency of reproduction can be attributed to persistent heavy grazing by livestock—more than 80 per cent of the wooded areas have been grazed for many years. Eastern hophornbeam, hawthorn, and American hornbeam are the major species in the reproduction of grazed stands. Elsewhere fire has been more important in preventing the establishment of seedlings, although locally, in these sections, pasturing has contributed heavily also.

The future establishment and development of reproduction under protection from fire and grazing varies greatly, such factors as the age and character of the stand and the condition of the seed bed playing a vital role. In the Ozarks and lower Ohio basin sprout

[1] Unpublished manuscripts of the author and of members of the staff of the Central States Forest Experiment Station, Columbus, Ohio, and *Station Notes* and *Technical Papers* of this station have been drawn upon freely for information contained in this chapter. *Station Notes* 5, 15, 16, 23, 30, 31, 32, and 33 and *Technical Paper* 105 are particularly enlightening.

reproduction usually develops in considerable quantity from old stools after a few years of fire protection. Apparently trees that develop from stool sprouts, except possibly the relatively few very large stools, are not defective (Liming and Johnston 1944). The establishment of seedling reproduction is limited in the younger stands by the small quantity of seed they produce. In the older stands seed production is

Photograph by U. S. Forest Service.

FIG. 47. Light selection cutting in a stand of oak and hickory. A well-stocked understory of seedlings, saplings, and poles has developed under protection from grazing.

adequate, but the seed may be severely damaged by insects. Sixty-seven per cent of the acorns of the 1937 crop in Missouri was infested by insects, and 98 per cent was defective from all causes (Kautz and Liming 1939). The 1938 crop showed similar conditions. Furthermore, rodents sometimes destroy much of the seed. In the northern part of the region, where sugar maple is a component of oak stands, more high-quality seed may be available because sugar maple seed is not so severely damaged.

If seed is not a limiting factor, seedling reproduction may not become established for several to 20 years, an unfavorable seed bed (a bare compact soil) being the critical factor. A deficiency of leaf litter

is probably the cause of poor germination of acorns in many cases. This was true in Ohio for chestnut oak, the seed of which germinated best and the resultant seedlings of which survived best in a loose leaf litter (the last season's fall of leaves) from 1 to 2 inches deep (Barrett 1935). Shade and other factors increase germination and survival of chestnut oak acorns and seedlings, respectively, only when the litter is deficient. In the corn belt a deficiency of soil moisture in the

Photograph by Purdue University Agr. Exp. Sta.

Fig. 48. Failure of reproduction in oak or beech–sugar maple forests under grazing will lead ultimately to the extinction of the forest.

A-horizon of the soil is probably the chief cause of the failure of seedling establishment in the more open stands that have developed a heavy grass sod (Day and Den Uyl 1932, Diller 1937). Even where a dense sod has not developed, deficient soil moisture, due to excessive run-off, may be the cause of the failure of reproduction during drought years. Soil moisture insufficient to sustain the life of tree seedlings may result also from one or more of the following conditions: sparse leaf litter, intense light, excessive wind movement, and dense surface vegetation (Den Uyl, Diller, and Day 1938) (Fig. 48). Stands in a less advanced stage of deterioration often reproduce successfully in about 5 years (Fig. 49). On the basis of existing information, it appears that improvement of the seed bed is the key to regeneration. Slash may have some value in this respect.

Since, with the exception of sugar maple, which is an important component of oak stands only in the northern part of the region, the high-value species that comprise the oak type are relatively intolerant, they do not survive well under a heavy canopy; those that do survive grow slowly. Chestnut oak seedlings in Indiana, when released by partial cutting, grew only slightly faster than those in an uncut stand. In a clearcut area they grew six times as fast as those in the partially

Photograph by Purdue University Agr. Exp. Sta.

FIG. 49. If deterioration of the seed bed has not progressed too far, regeneration may be abundant within 5 years after livestock are excluded. (Same area as Fig. 48, 5 years after grazing was eliminated.)

cut stand, but sprouts, owing to very rapid growth, quickly overtopped the seedlings in the clearcut area (Kuenzel and McGuire 1942). Blackjack oak seedlings are not a serious menace to the more desirable species because of their slower growth (Liming 1942).

On the other hand, the low-value species, flowering dogwood, red maple, sassafras, black tupelo, eastern hophornbeam, witch hazel, and others, being aggressive reproducers and tolerant, become established in abundance under a partial canopy. In openings seedlings of the high-value species have low mortality and make excellent growth, although exceeded in growth by sprouts of the same species. Both because sprouts often become established in advance of seedlings and because they grow faster, they have a distinct advantage over seedlings in any environment, and they will, therefore, unless controlled,

eventually dominate the stand. Under a partial canopy the tolerant low-value species are likely to get the upper hand.

Windfall. Most of the species of the oak types are characterized by a tap root, thus having low susceptibility to windfall. Windbreakage is limited chiefly to trees severely fire-damaged or severely infected with trunk rot.

Economic Basis

Utilization and Marketing Problems. Except in the corn belt, where the depletion of the supply of merchantable timber in recent years has led utilization plants to move elsewhere, good-quality timber can be marketed advantageously in a variety of forms. Especially where the demand for fuelwood, mine props, and fence posts is strong, relatively low-quality and small-sized material can be sold. The two most valuable species of the oak types are black walnut and white oak—the former for saw and veneer logs, the latter for saw logs and cooperage stock. White oak that can be cut into stave bolts is worth two or three times as much as that used for saw logs. Wherever there are handle factories, the ashes and hickories are among the more valuable species. There is an active demand in all sections of the region for cross-ties, made chiefly from the oaks. Some of the species that occur in limited quantity in the oak types—notably sugar maple and beech—can be marketed as basket stock. Piling, rustic-furniture stock, mine timber, and excelsior stock are other products that can be marketed in small quantities in some sections (Brundage 1934, Neubrach 1930).

The major problem in the Ozarks is profitable utilization of small quantities of high-quality wood and large quantities of low-quality wood from the seriously deteriorated stands. The extent to which large markets for low-quality wood can be developed have an important bearing on the cost of rehabilitating these stands.

Fuelwood is not easily marketed where there are local coal deposits.

In addition to black walnut and white oak, other high-value species are: white ash, northern red oak, bur oak, American basswood, black cherry, shagbark hickory, and yellow-poplar. Less valuable, but marketable, are black oak, post oak, and blue ash. Blackjack oak, eastern hophornbeam, American hornbeam, black tupelo, and serviceberry have little or no commercial value at present.

To produce wood that will yield high-quality products control of growth is essential. Table 23, which follows, shows, on the basis of

preliminary study,[2] the qualities that wood of the important species of the oak types should have to be suitable for different products and the rate of growth that gives these qualities.

TABLE 23

WOOD QUALITY AS INFLUENCED BY RATE OF GROWTH IN THE OAK TYPES

Species	Products							
	Stave Bolts		Saw Timber		Cross-ties		Handle Stock	
	Desired Qualities	Growth for Desired Qualities	Desired Qualities	Growth for Desired Qualities	Desired Qualities	Growth for Desired Qualities	Desired Qualities	Growth for Desired Qualities
White oak (group)	Heavy wood with maximum of heartwood	Not over 8 rings per inch in early life; 9 to 16 rings per inch in latter part of rotation	Similar to stave bolts	Not over 8 rings per inch	Ability to withstand great crushing load (any wood has adequate resistance)	Any rate of growth		
Red oak (group)			Medium density	9–16 rings per inch	Same as white oak	Preferably less than 8 rings per inch		
White ash and hickories			Light weight	Less than 15 rings per inch			Toughness	White ash less than 6, hickories less than 8 rings per inch

Although there are no specific data to substantiate the statement, trees under 12 inches in diameter at stump height probably cannot be utilized profitably for saw logs or cross-ties (Paton 1931).

[2] The data in Tables 23 and 25 are based on preliminary reports of the Forest Products Laboratory, Madison, Wisconsin.

Growth and Rotation. The best data on growth are those reported by Den Uyl (1944) for Indiana, where he found annual growth of 92 to 280 board feet (International ¼-inch rule) per acre over a 10-year period in permanent sample plots on site I. Growth varied with volume of reserve stand, species composition, and diameter distribution. Northern red oak made the fastest growth, followed in order by black oak, white oak, and hickory. He predicts that under good forest management growth per acre per year should be 300 board feet. Where present, white ash, yellow-poplar, basswood, and black walnut make rapid growth.

A rotation of 60 to 80 years, depending on the site quality, should produce good-quality saw logs.

Financial Aspects. There are no published data on the financial aspects of silviculture. What the cost of regeneration, either natural or artificial, may be is largely speculation, but it apparently varies greatly under the wide variety of stand and site conditions that are encountered. Natural reproduction on severely deteriorated sites left untreated would often be expensive in the long delay; on the other hand, an investment of \$1.00 to \$1.50 per acre for soil treatment might pay big dividends in stands with a satisfactory source of seed. Planting and the subsequent treatment of the area to insure seedling establishment often cost more than the former estimates of \$6.00 to \$10.00 per acre. On ideal sites the cost may be somewhat less.

Financial aspects of stand-improvement operations are equally variable. Where markets will absorb all the lowest-value material, a small profit may be realized on the operation. Where there is little or no market for such timber, cultural operations may cost several dollars per acre.

The strong demand and high prices paid for high-quality wood products in and adjacent to the region indicate that intensive silviculture pays in the long run.

Application of Methods

The meagerness of basic data—as demonstrated above—suggests that the application of silviculture to the oak types has little scientific foundation at present. Recommendations must be very general, therefore, and, in the final analysis, careful observation and nice judgment on the part of the practitioner must be the chief basis for satisfactory application.

Selection Cutting. Selection cutting is applicable to relatively few stands—virgin timber and well-stocked mature stands cut conserva-

tively in the past (Fig. 47). Whenever such stands are composed chiefly of saw-log trees or, lacking this characteristic, are situated where small trees can be marketed advantageously, a group-selection method of cutting, having as its objective the ultimate development of a stand even-aged by groups, should be used, except possibly in the northern part of the region, where more favorable soil moisture conditions and a larger representation of the more tolerant species make group cutting unnecessary. When soil moisture and species composition are not limiting factors, trees under 18 to 20 inches d.b.h. ordinarily should not be cut except for stand improvement. Group-selection cutting implies virtual clearcutting of small groups of trees and a light improvement cutting in the rest of the stand. Saw logs, cooperage stock, and piling as the primary products should be the objective in managing these stands.

On the poorest sites in the southern part of the region—ridges and south slopes—the pines should be favored by the retention of occasional seed trees because, there, the pines yield a better product in a shorter time than the oaks. Elsewhere the favoring of the species should be based on the intrinsic commercial worth of the species and local markets (p. 278).

Cultural Operations. Most of the oak forests must undergo a period of rehabilitation by cultural operations before they can attain their full production possibilities. Suggestions for the treatment of some of the more common types of deteriorated forests are given in the paragraphs that follow.

1. Light to Moderately Stocked Second Growth. The method of treating these stands should be determined by the quality of the site and the composition of the stand. If the site has average or better than average fertility and the existing stand contains some trees of high-value species, no trees should be removed until a well-stocked stand of reproduction becomes established, except possibly in large dense groups from which some of the less desirable trees should be eliminated, by cutting if the trees can be marketed, by girdling or poisoning if they cannot be marketed. The best small trees (those under 5 inches d.b.h.) should probably be pruned, but how many and what types of trees can be advantageously pruned have not been determined.

If the site and stand composition are poor, conversion to a pine or pine-oak type by planting shortleaf, pitch, or Virginia pine in the southern part of the region appears to be a logical policy. This is

then a planting problem that can be worked out from the details given on p. 283.

2. Culled Old Growth. Since most of these stands are heavily grazed, the first requisite to restoration is the exclusion of grazing animals.[3] Stands that have suffered deterioration through grazing may require special cultural measures. Whether such operations are needed and the character of the operations required are determined by the stage of deterioration a stand has reached. The recommendations made by Den Uyl, Diller, and Day (1938), based on several years' study in Indiana, should be applicable to grazed forests of a similar character in other parts of the region. Their recommendations are as follows:

Early stage—No special measures needed. After desirable reproduction becomes established, improvement can be accomplished through light partial cuttings.

Transition stage—Pawpaw and eastern hophornbeam must be eliminated. Pawpaw can be killed most effectively by poisoning; eastern hophornbeam by cutting at ground level (Diller and Marshall 1937). Seed trees of undesirable species in the overhead stand should be removed by a series of light cuttings over a period of 5 or more years. After a full stocking of reproduction of desirable species has been secured, well-planned cuttings further to improve the composition and growth of the stand should be undertaken.

Along the edges of the woods, especially the windward edge, a brush border should be maintained to minimize wind movement. In the more exposed areas, the planting of a windbreak may be justifiable.

Open park stage—The sod cover must first be broken. No effective method that accomplishes this and assures natural regeneration has been developed. Interplanting in furrows seems to be the most effective means of getting desirable species established. Removal of undesirable species in the overstory should be postponed until sufficient seedlings, regardless of species, have become established to assure the elimination of the sod. A windbreak on the west and southwest sides of these forests is desirable as an aid to the reduction of wind movement. Planted trees must be released early, and they should be weeded and cultivated for two or three seasons.

[3] It may be uneconomical to try to restore into productive forests, stands in the worst stage of deterioration occupying the best soils on relatively level ground. It may be better and cheaper to use some of these lands for agriculture and restore forest cover on poorer, eroded soils, if such exist on the farm in question. This is probably especially true of lands occupied by the beech–sugar maple and beech types.

Final stage—If more valuable for uses other than forests, these areas should be converted to such purposes. If they are to be employed as forests, planting is the only method that proves successful.

Similar treatment is applicable to grazed stands of the beech–sugar maple type. Since the more desirable species in this type are more tolerant than those in the oak types, release of reproduction can be more gradual.

3. Well-Stocked Even- or Uneven-Aged Second-Growth Stands. These stands need thinning or improvement cutting. When situated where mine props and/or fuelwood can be marketed, the cutting can be done when the stand is young and is able to benefit most. In the absence of such a market, the designated trees can be girdled or poisoned, or else cutting can be postponed until the trees are large enough for ties. Economic conditions should determine the plan that is adopted.

Pruning of some selected trees may be necessary, but, in general, natural pruning is satisfactory on most of the trees.

Planting. Planting is the only practical means of restoring forest on several million acres of eroded and denuded land. On most of these sites conifers or black locust must be planted, often as a temporary crop, but sometimes as a more or less permanent crop. Within their respective ranges shortleaf, pitch, Virginia, and loblolly pine in the south, eastern white pine in the north, and eastern redcedar in a large part of the region are recommended for extensive use because of their site adaptability (Chapman 1937) and their low susceptibility to destructive agencies (Polivka and Alderman 1937). Species selection should be based on site adaptability and local commercial value. On prairie soil, eastern white pine, as well as Scotch pine, Norway spruce, and European larch made excellent growth during the first 15 years, but thereafter slowed down more and more as age increased, until at 68 years of age these species had made a mediocre showing (Lorenz and Spaeth 1947). It is evident that these species are unsuitable for long-rotation products but may be satisfactory for fence posts, pulpwood, or small poles. For special purposes, such as Christmas-tree production, Norway spruce and possibly Fraser fir and Douglas-fir are suitable for the northern half of the region. In Missouri jack pine and Scotch pine have proved satisfactory Christmas trees. Eastern redcedar shows promise as a profitable fence-post crop (Arend 1947).

Native hardwoods, other than black locust, can be planted on sites that have not deteriorated. Black walnut can be planted successfully

on moist but well-drained soils of more than fair fertility. Particularly in the southeastern part of the region, where yellow-poplar was an important component of some of the oak stands, this species can be used for planting. For best growth, black walnut requires a deep, well-drained soil without pronounced subsoil development (Auten 1945*b*). Lime derived sandy loams, loams, or silt loams are particularly good. Best results with yellow-poplar is secured on sites with a deep (24 inches to subsoil), permeable, well-drained but moist soil and with protection from drying winds. The A-horizon of the soil should preferably be 3 inches or more deep (Auten 1945*c*).

In planting black locust, it should be understood that on many sites it will be only a temporary type. If maintenance of black locust as a permanent crop is desired, it must be planted in a soil to which it is well adapted, namely, one with a loose, well-drained but moist surface soil and a pervious subsoil that allows free movement of water. If planted in less favorable soils, such as those from which the top soil is eroded, growth may be improved by fertilization. On an eroded Bedford silt loam, height growth of trees fertilized with 1 tablespoon of 2-12-6 fertilizer per tree was one and one-half times and diameter growth was 1.75 times that of unfertilized trees (Den Uyl 1944). Survival was not affected, however. Other species, particularly the more tolerant hardwoods in mixture with black locust, are strongly recommended for the better soils. Conifers can probably be used in group mixtures but certainly not in individual stem mixtures.

Black locust is an excellent tree for controlling gully erosion. In Ohio it has proved satisfactory for stripped coal lands (Dean 1925).

In view of the generally unsatisfactory results that have been secured in planting open sites, there are strong indications that postponement of planting on such sites until an open stand of sassafras and/or persimmon becomes established is a better practice than immediate planting. Superior results on such tree-covered sites is probably due, in part, to better soil conditions (Auten 1945*a*).

Strip-mined coal lands constitute a special problem in forest planting. In Illinois, success has been attained on these sites with the following hardwoods: black locust; black walnut; northern red, black, white, and bur oaks; and white and green ash (Schavilje 1941). Shortleaf pine has been satisfactory in southern Illinois.

Spacing of black locust should be 6 by 6 feet except on severely eroded sites, where it should be 3 by 3 to 4 by 4 feet. One-year seedling stock of black locust and other hardwoods is recommended.

Plantations established for wood products should have the trees spaced 6 by 7 to 8 by 8 feet. Trees in Christmas-tree plantations should be spaced 4 by 4 feet.

Under average conditions 1-year seedlings of shortleaf, pitch, loblolly, and Virginia pine and eastern redcedar are suitable. On sites where competition from ground vegetation is intense, 1-1 stock of shortleaf pine is preferable (Chapman 1944). Three- or four-year transplants of eastern white pine, Norway spruce, and Douglas-fir are recommended.

Direct seeding appears feasible for the oaks, black walnut, and the hickories, but, until a technic is developed that will successfully overcome rodent pilferage and thus insure more consistent success, it cannot be recommended for extensive use.

Planting should be done in the spring of the year. In the Missouri Ozarks, however, satisfactory results have been secured in fall planting of shortleaf pine when 1-1 planting stock has been employed (Chapman 1944). Hole-planting appears superior to slit-planting in this region of predominantly heavy soils.

Slash Disposal

Because slash is small in volume, owing to the limited amount of timber removed in cutting, it does little damage to tree reproduction. Neither does it constitute a high fire hazard, even when first created, and at the end of 4 or 5 years it is in such an advanced stage of decomposition that the fire risk is negligible. For these and other reasons slash disposal is rarely necessary. In farm woodlands lopping is desirable on erosive sites; otherwise, no treatment is required. In the more extensive timber tracts, not on farms, disposal should take the same form, and, as an additional measure, areas that are outside the range of lookout towers should receive intensive fire protection for at least 2 years after cutting.

Disease and Insect Problems

Ecological Basis

Trunk rot, which is so prevalent in stands of any age, is directly traceable to infections that have entered fire wounds or the larger branch stubs, especially those over 2 inches in diameter.

June beetles, of which there are several species, cause serious damage in some localities, particularly in the northern part of the region. The

author has observed in southern Michigan the same species selection by this insect as reported in Wisconsin (Richter and Fluke 1935), namely, the white oaks in preference to the red oaks. Other species are seldom attacked. Recurrent defoliation for a few consecutive years results in the death of the weaker trees, especially during periods of drought. June beetles are most abundant where a heavy grass sod has existed in the woods or in fields adjacent to woodlands.

The *hickory bark beetle* attacks any of the hickories, frequently killing large numbers of trees. The cause of these attacks is unknown.

The *locust borer* attacks only black locust, chiefly in plantations rather than in the oak types. Slow-growing and unthrifty trees under 6 inches d.b.h. are most susceptible.

Control Methods

Trunk rots can be held in check effectively through fire control, prevention of physical injury to trees, development of well-stocked stands, and possibly some judicious pruning in existing understocked stands.

Control of the June beetle apparently depends on good farm management, such as keeping fields adjacent to woodlands in grass for not more than a few consecutive years, unless the control of erosion demands a different practice. It also requires good forest management, i.e., the breaking of grass sod in woodlands that support such a sod and conservative cutting practices as a preventive to sod formation where grass is not dense.

Maintenance of vigor and rapid growth of the trees is essential to the control of the locust borer. Careful selection of planting sites is the first requisite. The development of mixed stands, with the exception of individual stem mixtures of black locust and conifers, may reduce infestation. In slow-growing stands, cutting the stems, thus allowing sprouts to develop and thereby securing faster-growing trees, is advisable as a prevention measure. Clearcutting is probably best for severely damaged stands; thinning, thus improving vigor and growth of the remaining trees, is recommended for moderately injured stands.

There is no control known for the hickory bark beetle.

Control of Animal and Logging Damage

Because grazing in farm woodlands precludes a reproduction stand of high-value species, livestock must be kept out of these areas, except when they can be used for short periods for soil preparation (Fig. 49).

Hogs can be employed to advantage to break the sod in heavily sodded woodlands, if turned into the woodland in late summer before a large seed crop and removed just before seed germination, which in the case of white oaks is early autumn and in other species late spring (Day and Den Uyl (1932).

Light grazing by domestic livestock in the extensive tracts of oak forest in the southern part of the region may not be objectionable, but, in general, it is probably an uneconomical practice (Hill and others, 1937).

Greater care than is usually exercised in logging in the central hardwood region is necessary if logging damage is not to be a limiting factor in maintaining the stocking of cut-over land. More attention to felling the trees into openings should prevent much of the needless damage (Kuenzel and Sutton 1937).

BEECH–SUGAR MAPLE TYPE

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of the Forest. The two types, beech–sugar maple and beech, are described in Table 24 (Committee Report 1932).

The old-growth beech–sugar maple and beech types have been badly culled and usually grazed annually. These practices have caused serious stand deterioration. Limited areas of even-aged second-growth forest of moderate density are scattered through the region.

Stand Regeneration and Development. The younger second-growth forests support little or no reproduction. The older second-growth and the mature stands that have not been mistreated are usually well stocked with reproduction, sugar maple generally being the dominant species. Reproduction in grazed stands is chiefly American hornbeam, pawpaw, eastern hophornbeam, and hawthorn.

Protection from livestock and, in some cases, improvement of the seed bed are the keys to regeneration. Sugar maple, white ash, American elm, and slippery elm are prolific seed bearers, producing some seed nearly every year; therefore, a few large trees per acre should furnish ample seed for regeneration. In some sections, however, squirrels consume so much of the sugar maple seed as to interfere with sugar maple reproduction. Beech nuts suffer from squirrel pilferage as well as

insect damage. The seed bed in a stand that is in the final stages of deterioration as a result of grazing is unfavorable for seedling establishment. In a stand in a less advanced state of deterioration, the seed bed, although far from ideal, is adequate for establishment of a good stand of seedlings in a few years (Day and Den Uyl 1932). In one such stand in Ohio, abundant reproduction became established 3 years after protection from grazing, and by the middle of the eighth season seedlings numbered 80,000 per acre (Dambach 1944). By that time, considerable litter had accumulated on the soil surface. Sugar maple is one of the most aggressive trees, but white ash, American elm, slippery elm, and black cherry reproduce fairly well also.

TABLE 24

Description of Beech–Sugar Maple and Beech Types

Forest Types	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Beech–sugar maple	Moderate	High	Sandy loams, loams, silt loams, and clay loams in moranial hills of Ohio, central Indiana, and Michigan	American beech Sugar maple	Red maple White oak Northern red oak Hemlock Red elm American elm American basswood Hickories Black cherry Yellow-poplar White ash Black walnut Butternut	Climax type
Beech	Minor	Low to moder-	Flats of Indiana and along streams of hill sections where soils are poorly drained, chiefly in northern and eastern Ohio	American beech, pure or with minor associates	Sugar maple Yellow-poplar Pin oak Sweetgum Red maple Northern red oak White ash Slippery elm White oak Hickories	Climax type

Sprouts are an important form of reproduction only where young trees are cut, but they are not acceptable for the production of saw timber, especially in the northern part of the region, because they

develop poorly. The sprouts grow faster than seedlings, however, thus making it possible for them to overtop the seedlings.

Except for the greater abundance of such species as American hornbeam, pawpaw, eastern hophornbeam, and hawthorn, which may be present as advance reproduction, the composition of a new stand where the overhead canopy is sparse is likely to be similar to that of the original stand. If the overhead canopy is dense, as in a stand cut lightly by the selection method, sugar maple and beech have an advantage.

Windfall. On the wetter sites American elm and beech have shallow root systems that increase the windfall hazard there. On well-drained sites the windfall hazard is low. Windbreakage is confined to trees with physical defects.

Economic Basis

The silviculture of the beech–sugar maple types is influenced by just about the same economic factors that affect the silviculture of the oak types (see p. 278). Conditions that are different are discussed in the following paragraphs.

The beech–sugar maple types contain more material that is suitable for basket stock—a product that is in great demand in some sections, particularly Indiana—than the oak types. American beech, elms, yellow-poplar, white ash, and sugar maple are species occurring in the beech–sugar maple types that are in demand. Clear, sound, straight-grained logs or bolts at least 14 inches in diameter at the small end, and with a high percentage of light-colored wood, meet the requirements for basket stock (Brundage 1936). Basket stock generally brings a higher price than saw logs. Sugar maple and beech are also used for tool handles.

Rate of growth affects wood quality. The relation of growth to quality in the wood of the more important species of the beech–sugar maple type is show in Table 25.

For most uses to which basswood and yellow-poplar are put soft-textured wood is preferred. Although rapid growth (less than eight rings per inch) produces a relatively hard wood, such wood, if properly seasoned, can meet many of the demands.

Maple syrup can be produced profitably in the northern part of the region from stands containing a large percentage of sugar maple. Sap yield is materially affected by grazing of the forest. A 5-year study of two adjacent stands in Ohio, one grazed, the other ungrazed, demon-

TABLE 25

WOOD QUALITY AS INFLUENCED BY RATE OF GROWTH IN THE BEECH–SUGAR MAPLE TYPES

Species	Products											
	Lumber		Shoe Heels		Veneer Stock		Cross-ties		Turnery Stock		Pulpwood	
	Desired Qualities	Growth for Desired Qualities	Desired Qualities	Growth for Desired Qualities	Desired Qualities	Growth for Desired Qualities	Desired Qualities	Growth for Desired Qualities	Desired Qualities	Growth for Desired Qualities	Desired Quali-ties	Growth for Desired Qualities
Sugar maple	High degree of hardness	Preferably not more than 10 rings per inch	Must machine smoothly, hold nails and screws, and not split or chip readily	11–16 rings per inch	Conspicuous surface pattern	Preferably not over 10 rings per inch	High resistance to crushing	Less than 10 rings per inch	Uniformity of growth	For most purposes 11–16 rings per inch. For a better pattern less than 10 rings per inch	Large yield of pulp	Less than 10 rings per inch
American beech	Same as sugar maple											

strated an annual yield of $10.67 per acre more from maple syrup products in an ungrazed forest than in a grazed one (Dambach 1944).

Den Uyl's growth study (1944) in Indiana showed annual growth per acre of 96 to 345 board feet (International ¼-inch rule) under variable stand conditions. American elm made the fastest growth, followed in order by white ash, American basswood, and sugar maple. The saw-log rotation is 70 to 90 years.

Application of Methods

Cutting. In general, stands that are managed primarily for saw logs and other wood products should be handled in much the same way as the oak types (p. 280). There are some special problems in the beech–sugar maple types, however, that should be discussed at this point. The first of these has to do with the beech type, which, if it is to be most profitable to the owner, should be given intensive treatment to encourage a larger proportion of species other than beech. This must be a long-time undertaking, vigorously prosecuted in each cutting. If a stand contains practically nothing but beech, probably little progress can be made in changing the stand composition even over an extended period of time. If such is the case, artificial conversion by planting may be desirable, although there is no experience with this method upon which to draw.

Where the management of the beech–sugar maple type for maple-syrup production is feasible, cutting must be somewhat different from that in stands managed chiefly for timber production. Cutting should aim to develop as many large vigorous sugar maples as possible and to retain the large trees as long as they remain healthy and sound. Yellow-poplar, black walnut, white ash, and American basswood should be favored as associates of the sugar maple.

Planting. The need for planting either to restore badly deteriorated woodlands or to reclaim denuded lands is less acute on beech–sugar maple areas than on oak lands. Nevertheless, planting has a place in the silviculture of these types. Badly deteriorated stands supporting a dense sod can, in some cases, be rehabilitated most effectively by planting. Denuded lands and abandoned farm lands of this type present the same problem as in the oak types.

Planting technic should be the same as that used for the oak types, except for species selection. White pine for timber and Norway spruce, Douglas-fir, and Fraser fir for Christmas trees are best for deteriorated lands, whereas sugar maple, black walnut, yellow-poplar, and white

ash, preferably in some type of mixture, are suitable on the respective sites to which they are adapted for lands that show little or no deterioration.

Miscellaneous Silvicultural Problems

The slash problem in the beech–sugar maple types is similar to that in the oak types; therefore, slash should be treated in the same manner as in those types (p. 285).

Except in beech, which, regardless of its physical condition, becomes infected with rot-producing fungi at a relatively early age, serious rot is traceable to physical injuries caused by grazing animals, fire, logging, etc. Sprouts generally are attacked by rot when they are quite young. Control of rot is obviously dependent on the prevention of physical injury to the trees and reduction in the amount of beech as outlined under "Cutting" (p. 291).

White ash is often attacked by the oyster-shell scale. When the infestation is severe, the tree's vitality is lowered and ultimately, in some cases, the tree dies. There is no practical method of controlling this scale under forest conditions.

Control of animal and logging damage should follow the plan outlined for the oak types (p. 286).

SHORTLEAF PINE–OAK TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. The shortleaf pine–oak types are most extensive in southern Missouri and northern Arkansas but occur also in Kentucky and southern Ohio. Three forest types, the shortleaf pine–white oak, shortleaf pine–post oak, and shortleaf pine, are represented. They are similar to these types in other regions: the shortleaf pine–white oak type of the oak and southern Appalachian regions (pp. 106, 175); the shortleaf pine–post oak type of the oak, southern Appalachian, and southern pine regions (pp. 106, 175, 217); and the shortleaf pine type of the southern pine region (pp. 216–218). Virginia pine replaces the shortleaf pine in a few very restricted localities.

In all three types various oaks are prominent in the stand. Black tupelo, some of the hickories, and Virginia pine are minor associates.

The mixed stands of pine and hardwoods are usually uneven-aged; the stands made up chiefly of pine are generally even-aged. On the poorer sites the hardwoods are of low quality, being short and limby. Limited areas of virgin stands remain, but the bulk of the forest is second-growth, understocked, and with shortleaf pine in the minority.

Stand Regeneration and Development. Only limited study has been made of the regeneration problems. It is evident from the marked increase in shortleaf pine in the forests of Missouri that has gradually

Photograph by U. S. Forest Service.

Fig. 50. Shortleaf pine seedlings become established and make satisfactory growth where the stand is relatively open—canopy not over 20 per cent.

become established under fire protection since 1933 that fire protection is the first requisite to regeneration.

According to Liming's study (1945) in Missouri, one to five dominant shortleaf pines 12 to 18 inches d.b.h. per acre are needed to produce in a single year 1 pound of seed, which is the amount required for adequate reproduction. Apparently the condition of the seed bed does not have a strong effect on the initial establishment of shortleaf pine seedlings, since only one of four treatments—cultivation of soil after removal of litter—significantly increased seedling establishment. This relationship might not hold true for stands that have been under fire protection for a long period of years. Reduction in canopy from 80 per cent crown closure to 20 per cent produced no material effect on the initial establishment of pine seedlings, but it profoundly influenced seedling survival: nearly four times as many seedlings survived under the reduced canopy as under the untreated stand (Fig. 50).

Growth of the seedlings was affected strongly by canopy density, shortleaf pine seedlings under a 20 per cent canopy growing 33 inches and those under an 80 per cent canopy increasing 6.2 inches in height in 5 years. Suitable conditions for maximum growth of pine seedlings are essential if they are to compete successfully with hardwoods. In an experiment with planted shortleaf pine seedlings on a clearcut area, hardwood seedlings and sprouts made faster height growth than the pine seedlings during a 2-year period (Liming and Seizert 1943). In another experiment the development of planted pines varied directly with the amount of the canopy removed. Growth of pine seedlings was affected as far as 45 to 50 feet from standing overstory trees. Evidently pine encounters some difficulty maintaining itself under the natural competition that develops in mixed stands of oaks and shortleaf pine.

Windfall. All species develop deep roots and, for this reason, have low susceptibility to windfall.

Economic Basis

Utilization and marketing of the products of the shortleaf pine–oak types present much the same problems as in the oak types. Shortleaf pine, being the dominant species in the former types, needs special consideration here. The demand for this species as saw logs is strong, owing in part to its scarcity in merchantable size in many localities. Sawmill operators will accept logs 6 to 8 inches in diameter at the small end, obviously an uneconomical practice.

Although now only one pulpmill uses pine and, therefore, the demand for shortleaf pine pulpwood is very slight, it is likely that within the next 25 years, as the supply of shortleaf pine stumpage increases under fire protection and improved management, more pulpmills may be constructed in the region.

The most valuable species, stumpage value and rate of growth considered, are white oak and shortleaf pine. Pitch and Virginia pine in southern Ohio, Virginia pine in Indiana, and northern red and black oak through most of the range of the shortleaf pine–oak types are next in commercial value. Black tupelo and blackjack oak are the least valuable of the trees attaining saw-log size.

The shortleaf pine–oak types can be grown on a saw-log rotation of 60 to 80 years.

Although the financial aspects of various silvicultural operations have not been studied extensively, it appears that certain operations, such as stand improvement, can be accomplished at a cost that justifies

them in stands that have an adequate nucleus of high-value species. The release of crop trees spaced 17 feet apart has been accomplished for $3.24 per acre in northern Arkansas (Averell 1935), an investment apparently low enough to yield a satisfactory return.

At present, planting costs on open sites, because of the difficulty of getting a fully stocked stand established, are so high that there is some question as to the economic practicability of planting such sites until better planting technic is developed.

Application of Methods

Too little is known about the application of silviculture to the shortleaf pine–oak types, which have been studied only slightly in this region, to attempt more than a few generalizations.

Selection Cutting. Virgin or lightly cut mature stands can probably be reproduced most successfully by the selection method of cutting. Soil treatment may be necessary where the litter is too thick, but how this can best be accomplished and where it needs to be done are not known.

The productivity of the site should be a determining factor in applying selection cutting. On poor sites the pines should be favored; on good sites, although none of the more valuable species should be discriminated against, pine and the better oaks should be favored. Where pine is to be favored, the hardwoods should be cut as closely as the market will permit, and any low-value hardwoods that cannot be utilized should be girdled. No pine under 12 to 14 inches d.b.h. should be cut; and, if trees below this diameter are scarce, a few larger ones should be left for seed.

If hardwoods are to be an important part of future crops, high-value hardwoods under 18 inches d.b.h. and pines under 12 inches d.b.h. should ordinarily not be cut except for stand improvement. Low-value hardwoods should be cut or girdled.

Cultural Operations. Whether cleanings must be made in reproduction and sapling stands, either on clearcut or selectively cut areas, can be determined only by a field examination, since the extent to which the better species dominate the stand naturally varies greatly from one stand to another and the fundamental factors causing this variation are unknown. Pruning of both pines and the better hardwoods is probably advisable in the stands of large saplings and small poles, but there is insufficient evidence to suggest a desirable technic.

Improvement cutting or thinning must be applied to pole stands previously untreated. Unless the material can be marketed, the release

of crop trees, spaced 17 feet apart, by girdling appears to be the most practicable method.

Planting. Planting is essential on abandoned farm land and stands that will not reproduce or will reproduce very slowly because of inadequate seed trees. Planting technic should follow that outlined for the oak types (p. 283). Where underplanting is done, the following plan can be followed: plant 10 to 20 feet from an individual tree or a small clump, 15 to 25 feet from the edge of the stand, 15 to 30 feet from trees around the edge of openings, and 5 to 6 feet from overstory trees that are to be removed within 5 to 10 years. In stands of advance hardwood reproduction, pines should not be planted closer to reproduction than 2 feet or a distance equal to height of hardwood.

Miscellaneous Silvicultural Problems

Shortleaf pine slash has high inflammability for 2 years; but at the end of 4 years decomposition has advanced so far that most of the small branches have fallen to the ground, and at the end of 6 years decay has reduced its fire hazard to practically nil. Hardwood slash has much lower inflammability during the first 2 years because the leaves drop quickly, and thereafter its fire hazard is not much different from that of shortleaf pine slash because it rots at approximately the same rate.

In so far as is known, slash unless very dense, which it seldom is in this region, is more likely to be beneficial than detrimental to reproduction.

If cutting removes more than 2000 board feet of shortleaf pine, utilized only for saw logs, and elsewhere if the fire hazard is very high or if special protection is not practical, the pine slash should be lopped and the hardwood slash should be left untreated. Nowhere else need any of the slash be treated. In all cases special protection must be provided for 2 or 3 years.

Rot, most serious in hardwoods, is traceable almost entirely to mechanical injuries or large branch stubs. Fire prevention, control of mechanical injuries, and the development of well-stocked stands are the obvious solutions of these disease problems.

The southern pine beetle may attack the shortleaf pine under the same conditions as in other regions (see p. 179), but serious outbreaks seldom occur. Control of this insect can be accomplished in the same manner as in other regions.

A tip moth causes serious damage to shortleaf pine in many sections

of the region, especially outside of the natural range of the pine. Preliminary study of control measures indicates that spraying with concentrations of DDT as low as 0.48 per cent twice during a season, at the emergence of the first and second generations, is adequate (Afanasiev and Fenton 1947). Whether the results justify the cost has not been determined.

Control of animal and logging damage should follow the plan outlined for extensive timber tracts of the oak types in the southern part of the region (p. 286).

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9 · *Lake States Region*

DESCRIPTION AND HISTORY

Location and Landownership

The Lake states region lies in the northern half of the three Lake states, Michigan, Wisconsin, and Minnesota (Fig. 1). Practically all of it was originally covered with forest. Vast areas were cleared for farming in some sections. The poorer classes of farm land have been and still are being abandoned, thus adding to the acreage of forest land. Present forest-land area is estimated at approximately 56,000,000 acres.

Public ownership of forest land is increasing through acquisition and the reversion of lands to the states or counties for nonpayment of taxes. In 1948 slightly over 6,000,000 acres were in national forests, another 1,000,000 acres in other federal lands, nearly 6,000,000 acres in state forests, and nearly 2,000,000 acres in county forests.

Physiographic Features

The glacial action to which the region has been subjected has erased most of the sharp features of the topography. A large proportion of the region is relatively level to gently rolling, with slopes of less than 25 per cent. In some sections the land surface is practically level for miles, broken only occasionally by deeply cut river courses. These areas, situated above the general level of the surrounding country, have excessive drainage and become dry in midsummer. Dotted through the region are swamps varying in size from less than an acre to thousands of acres. Most of the region lies at an altitude of approximately 1000 feet. A strip of land about 50 miles wide along Lake Superior, the Porcupine Mountains in the northwestern upper peninsula of Michigan, and the Misquah Hills in northern Minnesota are distinguished from the rest of the region by a rougher land surface and a maximum altitude of over 2000 feet.

A great variety of soils, all podsolic, are represented by many soil types. Sands and sandy loams predominate. Locally peats and mucks or heavy clays occupy extensive areas. Generally speaking, the soils are deep, the result of extensive deposition during the glacial period. In the rougher sections, where rock outcrops are common, the soil layer is very shallow. Stones and boulders are abundant in some soils but almost entirely lacking on the sand plains.

Generally, the upland soils are finer in texture a foot or two below the surface than in the first few inches, but this fine-textured material gives way at greater depth to coarse-textured sand or gravel. The soils are acid in reaction, except in localities of limestone influence.

The region is noted for its many lakes. Lake Huron, Lake Michigan, and Lake Superior provide an extensive shore line. In addition to these, the interior is dotted with lakes too numerous to mention, varying in size from only a few acres to hundreds of acres.

Streams are also abundant. In Michigan, all the streams have their outlets in the Great Lakes, whereas in Wisconsin and Minnesota most of them flow south into the Mississippi River, although some of the drainage is into the Great Lakes and Hudson Bay. Many of the streams have a considerable fall over at least a part of their course.

Climatic Features

The climate has considerable local variation. This variation is due chiefly to the influence of the Great Lakes, which affect precipitation and temperatures, particularly. The climate is characterized by moderate precipitation, long, cold winters, short, cool summers broken by short periods of hot weather, and a humid atmosphere.

The average annual precipitation for most of the region is approximately 30 inches, but it ranges from 18.5 to 35 inches (Weather Bureau 1926). The wettest period is the growing season. In some sections as much as 75 per cent of the annual precipitation occurs during that time. Dry spells are not uncommon during their season, however. The driest period is late winter, usually February and March. Snow begins to fall rather early in the autumn, but rarely does it remain long on the ground until well into November, after which the ground is snow-covered almost continuously until late April. The average annual snowfall is 40 to 140 inches, most of the region having 60 to 100 inches (Weather Bureau 1926).

Situated as it is, close to large bodies of water, the region has a humid atmosphere, the relative humidity usually being above 60 per

cent. Periods during which the relative humidity is below 50 per cent, most common in summer and winter, are infrequent and of short duration.

The mean annual temperature ranges from 35° to 46° F. in different localities. The summer season, although generally rather cool, is subject to short periods of hot weather when the wind is in the south. The more inland points may register a maximum temperature above 100° F. during such spells. For extended periods the maximum temperature does not exceed 70° F. and the nights are cool. The mean temperature for July, the warmest month, ranges from 59° to 70° F. The winter is very cold. For most of the region, the range in mean temperature for January is from 6° to 12° F. (Weather Bureau 1926).

The length of the growing season varies considerably, being affected materially by location in relation to the Great Lakes. The cold waters of Lake Superior shorten the growing season of the extreme northern parts of the region by approximately 1 month. For most of the region the interval between the last killing frost in spring and the first killing frost in autumn is 3 to 4 months. Favored localities have an additional month free of such frosts.

Electrical storms, accompanied by strong winds and heavy rains, are common during the summer months. Sometimes these storms bring hail, which, with the high winds, may do considerable damage to trees through breakage. Lightning sometimes starts forest fires when precipitation is light.

Winds are variable but most prevalent from the northwest. The most destructive winds occur along the lake shore. Although the wind velocity is generally low, occasionally winds of high velocity and destructive force sweep some sections. Tornadoes occur at times in some areas.

Development of Lumbering

Commercial timber cutting in the Lake states began about 1835 in Michigan and Wisconsin. It developed at a rapid pace in this area, and before 1870 Michigan and Wisconsin were among the leading states in lumber production. The peak of production was reached in 1902, when nearly 9,000,000,000 board feet of timber—largely eastern white pine—were cut (Forest Service 1927). The Lake states region was then the leader in lumber production in the United States. As the supply of eastern white and red pine dwindled, cutting of hemlock and hardwoods began on a small scale. By 1914 hemlock production had reached its peak. When cutting of hardwoods finally became

extensive, some species, particularly beech, were seldom cut. Commercial cutting of beech for lumber and of spruce and fir for pulpwood developed greatly soon after 1900. At present, 85 per cent of the cut is hardwoods. Most of the pine, largely of inferior quality, is now cut in Minnesota. The annual cut of lumber in recent years has been between 1,000,000,000 and 1,500,000,000 board feet.

In Minnesota the crest of the lumber industry in terms of capital invested and value of product was passed in 1900. By 1910 the number of wood-using plants had dropped off considerably. The greatest development in paper and pulp was during the period 1910 to 1914 (Schantz-Hansen 1923). Since 1920 there has been a marked change in the character of wood-using industries in Minnesota. Sawmills have given way, to quite an extent, to pulpmills, box-board plants, and other wood-using industries able to employ the second-growth timber that is coming on the market in increasing volume. The evolution of the wood-using industries has been much the same in Wisconsin and Michigan.

Throughout the region, portable sawmills are being set up to utilize the smaller isolated tracts of timber.

The area of timber of saw-log size in 1945 was 6,470,000 acres. Pole timber, which in another 20 years will support considerable timber of saw-log size, had an area of 9,505,000 acres. Merchantable saw timber in 1945 had a volume of more than 50,000,000,000 board feet that was growing at a rate of approximately 1,400,000,000 board feet annually.

The Effect of Past Practices

The entire forest area, all of it originally in private ownership, has been badly managed. The earlier cuttings were very selective, operators removing only those species that could be marketed readily. The forests of eastern white and red pine suffered most damage because unmarketable species were less common in these forests than in others. Culling of the pine from the hardwood forests had little effect. As hardwoods became more generally salable, cutting of hardwood stands tended toward clearcutting. Ultimately all hardwood species were in demand, even in small size. On any operation only the most desirable and most merchantable trees generally are cut. If markets for chemical wood are good, close cutting is usually practiced. Before 1920, fire usually passed over cut-over land soon after cutting, leaving behind it nothing but waste. Because of this carelessness and lack of interest in the future of the land, approximately 14,000,000 acres of forest land

are either devoid of any tree growth or support only a poor to fair stand of reproduction. It is estimated that 7,500,000 acres of this land should be planted, if it is to come into profitable production in a reasonable length of time.

Since 1920, fire protection has saved much of the cut-over land from being converted into a stand of worthless weed species; but with little or no reserve stand on these lands sustained yield is impossible in most sections.

The development of public forests, begun in 1905, has been responsible for the improvement of a limited acreage of land. Reconstruction of these forest lands is being accomplished through fire protection, cultural operations, and planting. Fire protection has improved the stocking of large areas of forest. More recently natural stands and plantations have been improved on state and federal lands by Civilian Conservation Corps, which greatly expanded the forest-planting program. Through 1944, 1,393,000 acres of forest plantations had been established, 1,157,000 acres of which had been planted by public agencies. Seventy-five per cent of the plantations on public lands, or 813,000 acres were classified as successful. More than 90 per cent of the trees planted have been jack and red pine.

The Forests and Their Management

The forests of the Lake states are as diversified as the major soil groups. They are comprised of fourteen distinct forest types, several of them temporary types that followed fire. Relatively young second-growth forests predominate; virgin forests are in the minority, constituting less than 5 per cent of the forest. The most extensive types are the northern hardwoods, aspen (including scattered areas of paper birch), spruce (black spruce and white spruce–balsam fir–paper birch), red pine, and white pine. All except the aspen type have high commercial value. The jack pine and northern white-cedar are other types, less widespread, that are commercially valuable. The northern pin oak, tamarack, and pin cherry types are of secondary importance in area and commercial value. These three types are discussed here only briefly.

The northern pin oak type, actually a group of several scrub oak types, occupies certain red pine and eastern white pine sites that have deteriorated severely as a result of at least two or three fires (Kittredge and Chittenden 1929). Ecologically this type is comparable to the jack pine and aspen types in that it is a temporary type into which

the original occupants of the site gradually encroach. Many of the stands support some red and white pine reproduction, but less than 10 per cent of the area occupied by the northern pin oak type supports enough reproduction to provide a satisfactory nucleus for a pine forest (Kittredge and Chittenden 1929). Because the oak is of very poor quality, grows slowly, and yields little merchantable material at the time growth culminates, profitable use of the land depends on conversion to another forest type. Conversion by the methods outlined for the aspen type (see p. 337) are recommended, with eastern white, red, or jack pine used when planting is necessary (Allison 1931). Release cutting is essential as a follow-up measure.

The tamarack type, originally more important than now, may at some time in the future attain importance in forest management. It was almost completely destroyed by the larch sawfly many years ago, but in recent years tamarack seedlings have become established on some sites, where their growth has been remarkable. These habitats are similar to those occupied by the black spruce and northern white-cedar types, and the dominant species of these sites have taken possession of some denuded tamarack sites. Elsewhere speckled alder has come in thickly. Too little is known about the tamarack to speculate on its future.

The pin cherry type, occupying considerable area of clearcut or burned land, has no commercial value. It is a temporary type that, if left to nature, will be succeeded by an aspen or a northern hardwood type. Conversion to another type of commercial value is the logical objective in handling such stands.

NORTHERN HARDWOODS TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. The northern hardwoods types are three in number, the sugar maple–beech–yellow birch and the sugar maple, described fully on p. 29, and the sugar maple–basswood, which is peculiar to the Lake states region, especially Minnesota (Committee Report 1932). Intermingled with these types, particularly with the sugar maple–beech–yellow birch, are areas of hemlock type, which in the aggregate constitute a large acreage. Generalized information on the types as a group is given below.

Importance.
  Area—Major (9,445,000 acres).
  Commercial Value—High.
Sites Occupied—Loamy sands, sandy loams, loams, and, less commonly, silt loams.
Associated Species.
  Major—Varies with the individual type, but sugar maple, yellow birch, American elm, basswood, and hemlock are most common.
  Minor—Red maple, paper birch, white spruce, quaking aspen, red oak, downy serviceberry, pin cherry, American hornbeam, eastern white pine, balsam fir, eastern hophornbeam.
Place in Succession—Each type is climax for the sites it occupies.

Aside from a limited area of virgin forest, the original northern hardwood forest is cut-over and now represented chiefly by the following conditions: (1) culled stands, (2) clean-cut stands, largely unburned, (3) culled or clean-cut stands, heavily burned, (4) cleared land allowed to revert to forest, and (5) an aspen type (often following fire) (Buttrick 1926).

The second-growth forests are even-aged and irregularly stocked. Except for less white pine and hemlock, and sometimes yellow birch, their composition is similar to that of the virgin forests. The trees in many of the older unburned cut-over stands are rapidly approaching saw-log size.

The virgin forests are largely uneven-aged, with a remarkably even distribution of age classes (Watson 1925). Maissurow (1941) attributes this uneven-aged condition to recurring fires, which allowed new age classes to become established. The oldest trees range in age from 200 to 300 years, and they are usually 2 to 3 feet, but occasionally 4 to 5 feet, in diameter and 80 to 100 feet tall. Average volumes per acre over extensive areas are 8000 to 10,000 board feet, with individual fully stocked acres supporting 20,000 to 29,000 board feet (Westveld 1933*c*). The older trees generally contain a high percentage of defect.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction, with sugar maple dominant regardless of the composition of the overstory, is abundant in virgin and mature forests except in the limited area of farm woodland that has been heavily grazed. The general abundance of advance reproduction is reported from Michigan (Westveld 1933*c*) and Minnesota (Schantz-Hansen 1923). A study in Wisconsin revealed that, with the exception of sugar maple, all cases of abnormally abundant reproduction in virgin forests could be traced to surface fires (Maissurow 1941). Irregular

distribution, together with the destruction of some of the reproduction in logging, makes it desirable to provide in some way for subsequent reproduction.

Subsequent Reproduction. Sprouts develop from stumps after any method of cutting, but those originating from stumps over 4 inches in diameter are generally weak, poor in form, and therefore an undesirable element in a young stand.

The northern hardwoods are heavy seed producers[1] during good seed years, which occur every 3 to 5 years. Some seed is borne nearly every year. With the exception of beech nuts, which are consumed in large quantity by rodents, the seeds of the northern hardwoods escape serious injury by rodents. This fact is true also of eastern white pine and hemlock, both good seed producers.

The character of cutting influences the composition of the subsequent reproduction as well as the growth of subsequent and advance reproduction. Heavy cutting, particularly if it approaches clearcutting, discourages the regeneration of hemlock and eastern white pine (Buttrick 1926, Zon and Scholz 1929) and favors the regeneration of basswood, yellow birch, American elm, aspen, pin cherry, and paper birch, if seed trees of these species are near by (Buttrick 1921). Heavy cutting is followed also by the establishment of a dense stand of herbaceous weeds and shrubs, which, for a year or two, retard the growth of tree seedlings; but at the end of 5 years the seedlings dominate the vegetation (Eyre and Neetzel 1937) (Fig. 51).

Light cutting favors the establishment of sugar maple and hemlock seedlings, but, in general, the composition of the reproduction that becomes established after light cutting is not materially different from that of the original stand (Herbert 1924).

Exposure of the mineral soil, which will occur with summer and fall logging, aids the regeneration of yellow birch.

Effect of Competition. If there is a residual stand—as after selection cutting—growth of reproduction is slow except in openings. Sugar maple, beech, and hemlock seedlings have an advantage on such a site because of their high degree of tolerance; they grow slowly, but they live. White pine, aspen, pin cherry, and paper birch survive only in the openings. On a clearcut or heavily cut site these, as well as American elm and basswood seedlings, thrive and are likely to overtop

[1] Eight million seeds per acre were counted on a sample area after the heavy seed crop of 1934. These and other data in this chapter are taken from *Technical Notes*, *Station Papers*, and *Aspen Reports*, issued periodically by the Lake States Forest Experiment Station, St. Paul, Minn.

the slower-growing sugar maple, American beech, and hemlock seedlings. Although openings in a stand are essential to high survival of yellow birch seedlings, small openings (less than 0.1 acre) are more favorable than larger openings (over 0.1 acre). Survival was found to fall off substantially as the size of the openings increased, apparently

Photograph by U. S. Forest Service.

Fig. 51. Heavy cutting in an old-growth northern hardwoods stand creates a condition that temporarily is unfavorable to the growth of tree seedlings.

the result of excessive competition from shrubs and possibly overexposure to which yellow birch is very sensitive (Zillgitt and Eyre 1945). Height growth of the survivors is greater in large than in small openings, however. In openings of less than 0.1 acre, the proportion of yellow birch up to 3 inches d.b.h. in relation to all species is greater than that in the old-growth stands. In general, composition changes caused by competition between species are not great.

Growth of young hardwood stands after thinning at an early age varies with the character of thinning. Thinning of an 11-year-old stand which favored crop trees by their release on a 2.5-foot radius resulted in a small increase in total basal-area growth of crop trees.

but thinning that released crop trees on a 5-foot radius decreased the total basal-area growth of crop trees (Stoeckler and Arbogast 1947). American elm, basswood, and sugar maple showed good response to thinning, whereas white ash showed the least response.

Stand Decadence. Although Hall (1933) sounded a note of alarm over the severe decadence of the residual stand except under the lightest selection cutting, more recent studies show that mortality of trees, chiefly from windbreakage, in the reserve stand is no more than in the virgin stand—less than 1 per cent of the volume in 5 years (Eyre and Neetzel 1937).

Windfall. Windfall is a significant factor on uplands soils with a cemented B-horizon or an abundance of stones (conditions that restrict the root development of the trees) and on wet sites. Elsewhere windfall is uncommon. Windbreakage, not of destructive proportions, is worst on cut-over lands.

Economic Basis

Utilization and Marketing Problems. The most profitable use of most of the timber produced in the northern hardwoods types is saw logs. Chemical wood is in demand in some sections, particularly in northern Michigan, but the wood-distillate industry should be regarded as an outlet for small, inferior material down to 6 inches in diameter and the sound portions of large "cull" trees.

Based on commercial value, the more important species can be arranged in three groups in order of descending value: group 1, eastern white pine, sugar maple, basswood, yellow birch, and white spruce; group 2, American elm, hemlock, paper birch, red maple, beech, and balsam fir; group 3, aspen, eastern hophornbeam, American hornbeam, and downy serviceberry. This order of value does not apply to material that can be converted into veneer logs. In that form, yellow birch is worth 35 to 45 per cent more than sugar maple or American basswood.

Log diameter has a strong effect on profit derived from converting logs into lumber. In a study published in 1930, 20-inch logs were worth more than fifty times as much as 7-inch logs (Zon and Garver 1930). Stumpage value was increased more than 30 per cent by raising the cutting limit from 9 to 17 inches.

Growth and Rotation. Increment in cut-over stands varies widely, the volume of the reserve stand being the most important single factor in growth differences. After clearcutting annual growth per acre was only 55 board feet, whereas after selection cutting it has varied from

106 to 267 board feet, Scribner rule (Duerr and Stoddard 1938, Eyre and Neetzel 1937, Zon and Scholz 1929). When 3000 to 6000 board feet per acre in thrifty trees was left in the reserve stand, the growth in 12 to 20 years replaced the volume that had been removed. Maximum growth on good sites has occurred on a reserve stand of 6000 board feet per acre in trees 10 inches d.b.h. and larger per acre (Zillgitt 1947). Mortality, chiefly from suppression, windfall, and logging injury, in selectively cut stands has been similar in two studies—29 and 32 board feet per acre annually, respectively (Duerr and Stoddard 1938, Eyre and Neetzel 1937). In general, differences in growth of the major species in the stands and of trees of different diameters are small.

Eastern white pine, American basswood, and American elm, abundant locally, but sparsely represented or absent generally, are the fastest-growing species.

The production of saw logs requires a long rotation—probably 125 years on an average quality site, but not less than 100 years on the best sites. Immature stands contain considerable board-foot volume at 60 years,[2] but the trees are too small and of too low quality to be converted into lumber profitably.

Financial Aspects. Selection cutting has financial advantages over clearcutting. One study demonstrated that the greatest profit per thousand board feet accrues from cutting to an 18-inch d.b.h. limit (Zon and Garver 1930). This is due in part to the fact that the proportion of high-grade lumber recovered from large trees is greater than that recovered from small trees (Stott 1943). One study shows a net annual return per acre of $0.18 from clearcutting and a return of $1.08 from selection cutting on a 20-year cutting cycle (Zon and Garver 1930). In another study the net annual return per acre in 12 years from a selection cutting that removed 6000 board feet per acre (50 per cent of the saw-log volume) was $0.83 (Duerr and Stoddard 1938). These returns are equal to 4 to 8 per cent on the investment (Buell 1937). A recent analysis of several types of selection cutting revealed that the greatest interest return on the reserve stand is realized when the reserve stand has a volume of 3000 to 4500 board feet per acre in trees 10 inches d.b.h. and larger.

Although some research has been done on nonrevenue thinning in young hardwood stands, the results do not demonstrate whether such

[2] A 60-year-old fully stocked stand measured by the author had a volume of 12,400 board feet per acre, 78 per cent of which was contained in trees between 10 and 13 inches d.b.h.

operations are economically feasible (Stoeckler and Arbogast 1947). There is some indication that pruning of branches under 1 inch in diameter on small trees might increase timber quality enough to justify the expense.

Application of Methods

Selection Cutting. Selection cutting is recommended for virgin stands and mature stands of second growth because it combines the

Photograph by U. S. Forest Service.

Fig. 52. Selection cutting in the northern hardwood forest, with the slash left scattered on the ground. A second cutting can be made in 15 to 30 years.

maximum advantages financially and silviculturally (Fig. 52). Although each operation and stand must be studied before the diameter limit for cutting can be set, in general it appears that trees below 17 or 18 inches d.b.h. should not be cut (Watson 1925, Zon and Garver 1930). This allows for the removal of 30 to 40 per cent of the volume of the stand and makes a second cutting possible in 15 to 30 years.

To secure the best results silviculturally, great care must be taken in the selection of trees that are cut. Stand decadence can thereby be minimized and advance reproduction can be released. An effort should be made to remove trees that are small for their age and trees that show any indication of invisible, as well as visible, defects in the trunk, as a precaution against losses from windbreakage and other forms of stand decadence (Eyre and Neetzel 1937, Hall 1933). Release

of advance reproduction should be one aim of cutting if the plan is not otherwise objectionable.

On sites to which yellow birch is well adapted, this species may be encouraged advantageously through the size of the openings created in the stand. Group-selection cutting that creates openings of less than 0.1 acre is recommended for yellow birch (Zillgitt and Eyre 1945).

Eastern white pine and eastern hemlock should be especially favored on sites to which they are well adapted. American basswood and American elm should be encouraged on the more moist locations.

On sites of high windfall hazard it may be safest to practice clearcutting, if advance reproduction is abundant.

Cultural Operations. Cleanings apparently are not essential to the maintenance of vigorous growth of young hardwood stands. Since the economic value of such cuttings has not been demonstrated, it appears best to postpone cultural operations until the material removed can be marketed.

Pruning shows enough promise in improving timber quality to suggest use at least on a broad-scale experimental basis (Stoeckler and Arbogast 1947).

Thinning and improvement cutting are essential to the maintenance of satisfactory growth and the development of a desirable composition. In localities where chemical wood, mine timbers, and cross-ties can be marketed, thinnings can be intensive, each thinning removing approximately 20 to 25 per cent of the volume at intervals of 10 to 15 years. In the absence of markets, heavy release of crop trees only, by girdling, is recommended. The objective in these cuttings should be the release of a maximum number of the trees most valuable for saw logs.

Slash Disposal

Slash in Relation to Fire

The fire hazard created by logging slash varies with the amount of timber cut, the method of cutting, and the degree of utilization. Selection cutting leaves a relatively small volume of slash, which is kept moist and therefore at a low point of inflammability by the residual stand. If, on selectively cut areas, chemical wood is utilized, the slash hazard is relatively low. In contrast, clearcut areas on which utilization is for saw logs only have a high slash hazard. Slash on clearcut areas is hazardous for 8 years; on selectively cut areas, for 4 years (Zon and Cunningham 1931).

Economic Considerations

Although no studies of slash-disposal costs have been made recently, it is generally conceded that costs of either piling and burning or lopping are entirely too high for the benefits they produce. Since cutting areas are generally small and usually cut selectively, intensive protection of cut-over areas is a much more economical method of handling the increased fire hazard created by logging slash.

Application of Methods

To reduce the fire hazard, small material suitable for chemical wood should be utilized wherever marketable. On selectively cut areas, additional treatment of slash is usually unnecessary. Intensive protection should be provided for a period of 4 years.

Disease and Insect Problems

Rot-producing fungi are the worst enemy of the hardwoods. With the exception of sprouts or wounded trees, rot is not serious in trees under 150 years old. The shoe-string fungus frequently invades trees that are injured in logging, playing a secondary role in their decadence (Hall 1933). Much of the windbreakage in mature trees is traceable to trunk rots. American beech, yellow birch, and basswood are more susceptible to decay than their associates, and their wood rots more rapidly, once they are infected.

Satisfactory control of the rots can be effected by the removal of infected and injured trees and sprouts in cultural operations (p. 311), and by the prevention of damage to the trees in all phases of logging.

The *spring cankerworm*, a defoliator, strikes periodically, causing the death of numerous trees in the suppressed, and some in the intermediate, crown classes. Larger trees probably suffer some retardation in growth.

No practical method of controlling the spring cankerworm has been developed.

Control of Animal and Logging Damage

The control of domestic livestock requires attention only in farm woodlands; elsewhere there is so little grazing that it is not harmful. Livestock must by all means be excluded from farm woodlands.

Where girdling of young trees by porcupines is serious, reduction of the porcupine population by poisoning is advisable.

Since carelessness appears to be the chief cause of excessive damage in logging, close supervision is the best method of control.

WHITE PINE TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest. At present the white pine type is of minor importance commercially because most of it is unmerchantable second growth. In future years this situation will change. Detailed information of the type follows.

Importance.
  Area—Minor.
  Commercial Value—Eventually high.
Sites Occupied—Chiefly sandy loam uplands, except in Minnesota, where it occupies loams (Corson, Allison, and Cheyney 1929).
Associated Species.
  Major—In natural stands, on sandier soils, eastern white pine and red pine; on loamier soils, eastern white pine, paper birch, yellow birch, sugar maple. In plantations, eastern white pine (often pure).
  Minor—In natural stands, on sandier soils, quaking aspen, red maple, pin cherry, white oak, northern red oak; on loamier soils, black cherry, American basswood, balsam fir, hemlock. In plantations, quaking aspen and paper birch (natural growth).
Place in Succession—A permanent type on sandier soils. Fires cause retrogression to species of low commercial value (Zon 1928).

Both natural stands and plantations are even-aged. Stands of reproduction, sapling, and pole size predominate. The natural stands are irregularly stocked and understocked. Plantations are generally well stocked.

Stand Regeneration and Development. Since the mature stand occupies so little area and little is known about the natural regeneration of white pine in the Lake states, the problems of natural reproduction will be dismissed with a few words. The general tendency in white pine stands as they approach maturity is toward the establishment of numerous hardwood seedlings but few pine seedlings. It has been observed that the environment created by selection cutting is favorable to the establishment of white pine seedlings. Growth in height of white pine seedlings is fastest also on such a site (Shirley 1932).

Rabbits frequently interfere with the establishment of planted as well as natural pine seedlings in some localities, notably in Minnesota (Corson and Cheney 1928) (see p. 316).

Hardwoods are an obstacle to the normal development of eastern white pine seedlings, both in naturally and in artificially established stands. The slow initial height growth of the pine seedlings and the rapid growth of the hardwood seedlings and sprouts (chiefly red maple, quaking aspen, and paper birch) give the hardwoods a great early advantage. Not only is growth of the pine retarded, but the seedlings that survive suffer severe physical injury from the whipping of their tops and laterals by the hardwoods. In very dense stands some of the pine die. In young plantations transplants cope with the hardwoods more successfully than seedlings.

More detailed information on the regeneration and development of the white pine type, much of which probably applies to the Lake states region, can be found on pp. 44 to 48.

Windfall rarely occurs because eastern white pine and its major associates have well-developed, deep root systems.

Economic Basis

From a commercial standpoint eastern white pine is the most valuable species. On sites to which they are well adapted, balsam fir, eastern hemlock, American basswood, red pine, sugar maple, and yellow birch develop into trees of commercial size and form. On the drier sites their growth and form are so poor that they have little commercial value. Aspen, paper birch, and red maple rarely can be marketed to advantage.

Saw logs are the most valuable product derived from white pine. In some sections where there are paper mills small white pines down to 5 inches d.b.h. can be marketed as pulpwood.

Pulpwood can be grown on a rotation of 40 years and saw logs on a rotation of 80 years on an average site (Gevorkiantz and Zon 1930). Except on the sandier soils, where red pine exceeds it in rate of growth, white pine is the fastest-growing species in the white pine type, and it maintains or increases this superiority into late life.

Although the yield and value of the products of the white pine type are high, so are the costs of producing a valuable crop. The cost of successfully reproducing a stand naturally is not known.

If pulpwood can be sold, thinnings yield a profit.

APPLICATION OF METHODS

Selection Cutting. Selection cutting is recommended for mature white pine stands, because it perpetuates the type most effectively and economically. Approximately 75 to 80 per cent of the volume of the stand should be removed (Zon 1928). Included in the trees that are cut should be the largest trees of all species, except a few white pines over 15 inches d.b.h. wherever seed-bearing trees are deficient in number, and most of the hardwoods unless they are well adapted to the site. In any event some hardwoods should be retained for soil improvement. Unless jack pine can be readily marketed as pulpwood it should be cut closely, and in no case should it be allowed to gain an upper hand. Wherever advance reproduction of high-value species is established, a special effort should be made to reduce the canopy to a density of not more than 50 per cent, if white pine is the chief component of the reproduction, and to not more than 30 per cent, if red pine is the chief component.

Cultural Operations. In any young stands in which hardwoods and jack pine constitute more than 30 or 40 per cent of the stand, cultural operations are imperative. They should begin early—not more than 3 years after the stand is established—and continue until the stand is mature. The cleanings must be intensive if the hardwoods are abundant—three to five annual cleanings that remove the vegetation as well as trees. In stands containing fewer hardwoods, the intensity and frequency of the cleanings can be reduced in accordance with the abundance of the hardwoods. There should be thinnings, later on, of the same character as outlined for pole stands.

Sapling and small pole stands that have grown up uncared for are sorely in need of treatment. All the competing hardwoods should not be removed, especially not where the white pines are so small that they are susceptible to the white pine weevil, because otherwise severe damage occurs from attacks by this insect (Schantz-Hansen 1937*a*, Young and Eyre 1937). Girdling is preferable to cutting of the larger quaking aspen, because suckering is thereby reduced. If suckers or sprouts develop, a second treatment will be necessary if the pine is smaller than sapling size.

Thinning can begin at an age of 20 to 25 years when the trees are 5 to 6 inches d.b.h. and therefore suitable for pulpwood. Removal of 20 to 30 per cent of the cubic-foot volume at intervals of 10 to 15 years is recommended when the material can be marketed.

Pruning, following the technic outlined for white pine in the New England white pine region (p. 55), is recommended.

Planting. The discussion of planting at this point will deal with practices on denuded or partly denuded land. There is as large (or larger) an area of white pine land now occupied by the aspen type needing somewhat different treatment (see p. 337). If there is a hardwood cover of more than 30 to 40 per cent, most of it should be cut or girdled before planting, leaving a scattering of trees for protection. Eastern white pine should be used on the better soils, red pine on the poorer soils. Other factors, particularly overhead cover, low ground cover, and water table, should also be considered in the choice of species for planting in the white pine type as well as other types. An excellent basis for evaluating the suitability of different species for various sites in Wisconsin has been developed (Stoeckler and Limstrom 1942). Since the principles developed in this site classification are probably applicable to other parts of the region, this article should be consulted before making a choice of species for a given site. In considering only pine sites, the classification developed by Maissurow (1939) should be useful.

Mixtures should be used when it seems feasible. Three-year (2-1) white pine transplants and 2-year red pine seedlings are suitable for white pine sites. Spacing should be 6 by 6 feet.

The details of planting technic which follow apply to planting sites of other forest types as well as white pine planting sites. Adherence to the following practices will increase plantation survival and growth:

1. Plant in spring instead of fall (Rudolf 1939, LeBarron, Fox, and Blythe 1938).

2. Be careful not to cramp roots in planting hole (Rudolf 1939). Evidence is not conclusive as to whether the type of tool may be the cause of excessive root cramping. Rudolf (1939) suggests that the use of the planting bar may be the cause, but Schantz-Hansen (1945*a*) found no appreciable difference in survival of 4-year transplants planted with three types of tools, including the planting bar.

3. When possible, plant on north and east sides of existing cover to increase survival (Rudolf 1939).

4. Prepare the planting site by the plowing of furrows (Kittredge 1939).

5. Precautionary measures, which should include the following, should be taken on sites where danger of excessive damage by rabbits is apparent (Aldous and Aldous 1944): (*a*) confining planting to open areas during periods of high rabbit population and (*b*) limiting the

planting of areas in low brush cover and those adjacent to swamps to the low periods in the rabbit-population cycle and using large thrifty stock. Supplementary measures that may be less applicable include: (*a*) using repellent sprays either in the nursery or in the field, (*b*) hunting and snaring of rabbits to reduce population, (*c*) applying poison in a selective manner, and (*d*) supplemental felling of aspen in coniferous plantations during peak population periods.

Slash Disposal

Slash in the white pine type constitutes a fire hazard that is high at first, diminishes slowly, except in the late stages of decomposition, and is completely gone after 12 to 15 years (Zon and Cunningham 1931). The relative dryness of the sites accentuates the slash fire hazard. The small size of cut-over areas is a compensating factor in the degree of slash fire hazard.

Slash disposal is unnecessary after thinning or other intermediate cuttings. Cutting in mature stands must be followed by some disposal, either partial disposal by swamper burning or piling and burning. The amount of burning should be determined by the degree of fire hazard. Disposal of slash on strips covering no more than 25 to 30 per cent of the area is ordinarily the maximum amount of disposal needed on the most hazardous areas. Generally, much less disposal is necessary. Intensive protection must be applied for 6 to 8 years.

Disease and Insect Problems

The *white pine blister rust*, established on the currant and gooseberry bushes for many years, has infected the white pine in some localities. Control is achieved through eradication of currant and gooseberry bushes.

The *white pine weevil*, although observed in various sections, has not caused severe damage. Since it has been most destructive where an understory of white pine has been given full release (Schantz-Hansen 1937*a*, Young and Eyre 1937), leaving a small amount (possibly 20 per cent) of the hardwoods, in release cutting, will aid its control. Limiting of pure plantations of white pine to relatively small areas is also recommended as a control measure.

Several species of Ips and the red turpentine beetle breed in the larger parts of white and red pine slash. Although generally conceded to be of secondary entomological significance (Division of Forest

Insect Investigations 1927), the Ips, having increased in numbers after breeding in slash from thinnings, have attacked and damaged numerous trees in northern Minnesota. Thinning in winter and immediate disposal by piling and burning of the slash resulting therefrom may be advisable where the Ips beetle is likely to be troublesome.

Control of Animal Damage

Grazing by domestic livestock is of such minor importance that it does not need special attention.

Control of the rabbit population is essential wherever there is evidence of severe rabbit damage on the pine. The leaving of a few scattered trees or snags as roosts for hawks and owls may provide adequate control in the less critical areas (Rudolf 1939). Other measures for combatting rabbit damage have been discussed elsewhere.

Emphasis should be placed on the prevention of overpopulation to check deer damage, but the planting and the maintenance of occasional groups of plants that make acceptable browse for deer are often advisable also (Rudolf 1939).

RED PINE TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest

Importance.
- Area—Minor.
- Commercial Value—Secondary because the stands are chiefly unmerchantable second growth.

Sites Occupied—Sands, gravels, and dry sandy loams.

Associated Species.
- Major—In natural stands, red pine (often pure), jack pine, eastern white pine. In plantations, red pine, either pure or with jack or white pine.
- Minor—In natural stands, jack oak, white oak, northern red oak, paper birch, quaking aspen. In plantations, a limited amount of the foregoing, sometimes.

Place in Succession—Generally regarded as temporary to be succeeded by white pine, although, on the driest sites, it may be permanent. Jack pine and oaks succeed it when burned.

Red pine stands are even-aged, and the majority of them are under 35 years old. Understocking is typical, even the plantations showing

some thin spots. The older red pine stands are rarely dense, a condition that allows grasses and other herbaceous plants to form a fairly heavy cover on the forest floor. A large acreage of land originally occupied by red pine is now covered by a partial stand of jack pine and oaks.

Stand Regeneration and Development. *Advance Reproduction.* Stands 40 or 50 years old generally support some advance reproduction

Photograph by U. S. Forest Service.

FIG. 53. Red and jack pine seedlings have grown up in an opening in a mature red pine stand. A fairly open site is a requisite to the establishment of red and jack pine seedlings.

of hardwoods, chiefly red maple and various oaks, but red pine reproduction is sparse or lacking, except in openings, where it may be abundant (Schantz-Hansen 1922) (Fig. 53). In older stands with canopies of 50 per cent or less, advance reproduction may be fairly abundant.

Subsequent Reproduction. Subsequent reproduction is slow in becoming established unless conditions are just right. A deficiency of seed may be limiting. Good seed years do not occur oftener than every 3 to 5 years and may be as infrequent as 7 years (Eyre and Zehngraff 1948). Squirrels sometimes reduce the potential seed supply by cutting off many cone-bearing branches (Cheyney 1929), and rod-

ents and birds frequently consume a large proportion of the seed before it works its way into the soil (Shirley 1933).

When red pine seed is abundant, good germination and establishment of seedlings apparently depend upon a well-prepared seed bed. In an experiment in soil preparation a disked soil supported more than twelve times as many seedlings (10,620 per acre) 2 years after germination as an untreated soil, and 70 per cent of the former area was occupied by reproduction as compared to 14 per cent of the latter area (Shirley 1933). The investigator attributes the more successful reproduction on the treated soil to a combination of factors—protection of the seed from rodents and birds, better root development, shading of the seedlings by the irregular soil surface, and removal of competing vegetation.

The amount of overhead canopy influences red pine seedling establishment. A light intensity of 35 per cent, found where approximately two-thirds of the canopy in an average forest is removed, is ideal (Shirley 1932). A light intensity of less than 17 per cent makes establishment uncertain. This fact probably explains why red pine seedlings become established in only small numbers on clearcut areas, where, invariably, a heavy cover of brush and other vegetation develops soon after cutting, thus reducing light intensity to a low point.

The hardwoods reproduce after cutting from suckers and sprouts. This subsequent reproduction, together with the advance hardwood reproduction, may be as abundant as the pine reproduction in some stands.

Competition between Pine and Hardwoods. Because of their rapid growth hardwood sprouts quickly overtop red pine seedlings. The immediate effect of this competition between elements is a marked reduction in growth—sometimes as much as 100 per cent—of the red pine seedlings (Fig. 54). The ultimate effect is the death of many pine seedlings. These same effects can be observed in many plantations 6 or 8 years after planting (Eyre 1933*a*). Where the hardwoods are dense, reversion to a hardwood type—usually aspen or paper birch—may occur as a natural development. Released from the hardwood competition, red pine reproduction or saplings increase in height one and one-half to two and one-half times as fast as before release, the growth being more or less proportional to the amount of release (Lake States Forest Experiment Station 1935).

Windfall. Red pine and its associates develop deep, widespreading root systems that make them highly resistant to windfall. Windbreakage rarely occurs.

Photograph by U. S. Forest Service.

Fig. 54. Fifteen years after planting, this red pine is seriously suppressed by aspen. The effect of suppression on growth is evidenced by the difference in the size of the pines at the left. Superior National Forest, Minnesota.

Photograph by U. S. Forest Service.

Fig. 55. The same stand as in Fig. 54, after part of the competing aspen has been removed.

Economic Basis

On most sites red pine is the most valuable species. On the best sites, however, the white pine attains good form and grows as fast as, or faster than, red pine. It is, therefore, more valuable than the red pine on such areas. Jack pine, although not so valuable as the other pines for saw timber, is in strong demand as pulpwood, and for this purpose may be as valuable as the other pines are for saw logs.

Small saw logs can be grown in 80 years, but, since growth continues satisfactorily for many more years and quality improves, a rotation of 140 years appears best for saw-log production. This plan implies systematic thinning in young stands. In one case a stand of high density thinned at 15 years to a spacing of 7 by 7 feet had maintained for 15 years better growth than similar stands thinned to narrower or wider spacings (Schantz-Hansen 1945*c*).

Although not applied extensively, soil preparation by disking appears, on the basis of the vastly superior reproduction on disked sites, as a good investment if natural reproduction can be relied upon. Where artificial regeneration must be resorted to, planting is more economical than direct seeding, if the proper class of planting stock and the proper technic are used (Rudolf 1939, Rudolf and Gevorkiantz 1935, Shirley 1937). Neither in plantations nor in natural stands can a valuable timber crop be expected without the application of cultural operations during the early years of the stand's development. In red pine stands supporting more than an average amount of hardwoods, cleanings removing 40 and 90 per cent of the hardwood basal area have been accomplished in 3½ and 6¼ man-hours per acre, respectively (Eyre 1933*b*).

Application of Methods

Shelterwood Cutting. Red pine stands can be regenerated most satisfactorily by a shelterwood system. Thinnings late in the life of red pine stands may result in an adequate stand of reproduction and thus dispense with the necessity of preliminary cuttings. In the absence of reproduction the seed cutting can be made 10 to 15 years before the final cutting. Approximately one-half of the merchantable volume of the stand should be removed. Five to 8 years after reproduction has become established, the removal cutting should be made (Eyre and Zehngraff 1948).

Soil Preparation. Soil preparation, preferably just before cutting, is recommended as a part of the plan to promote natural reproduction.

The disking methods employed in the jack pine type are suggested (see p. 328).

Cultural Operations. Cleanings are essential in practically all sapling and pole stands previously untreated—plantations included—and in many of the younger stands that have been previously treated once (Figs. 54, 55). In plantations the first release cutting can be postponed until 6 to 8 years after the establishment of the plantation. In such cases a single cutting may be adequate. This method does not apply to plantations established to replace a quaking aspen stand, which presents an entirely different problem (see p. 337). In stands of natural reproduction containing many hardwoods, release cutting must start 3 or 4 years after the reproduction cutting and must be applied two or three times. If hardwoods are not abundant, a single cleaning 5 or 6 years after the reproduction cutting may suffice.

Thinning is certainly desirable silviculturally, but, unless jack pine and white pine can be removed for pulpwood, thinnings cannot be intensively applied. In natural stands under 30 years of age, low thinning to a spacing of 7 by 7 or 8 by 8 feet appears most promising. The advisable frequency of thinnings has not been determined. A tree classification based on crown position, crown density, soundness, form, and utility has been developed to aid in the choice of trees to be removed in thinning red pine as well as aspen and jack pine (Gevorkiantz, Rudolf, and Zehngraff 1943). Details of applying the scheme are not outlined by the authors, but they suggest cutting the least vigorous trees of least desirable form and utility, as a rapid-growing, sound stand of high future usefulness can thus be retained.

Pruning is undoubtedly desirable, but the details of its application have not been worked out.

Planting. Planting is necessary on lands occupied by a scattered stand of oaks and jack pine, unless the owner wishes to encourage conversion into a jack pine type by natural means. Red pine is the most satisfactory species for the general run of sites, but jack pine is probably better as a permanent crop for the sandier soils and as a temporary crop on badly deteriorated sites. Where red pine is used, 2-1 stock should be planted on the poorer sites and 2-0 stock on the better sites, the latter case requiring the trees to be placed closer together (Rudolf and Gevorkiantz 1935). In a nursery fertilizer experiment, 2-0 red and jack pine planting stock grown in the nursery and heavily treated with a balanced fertilizer did not have higher survival, but it did make greater height growth than similar, unfertilized stock (Wilde, Wittenkamp, Stone, and Galloway 1940). On a Plain-

field sand in Wisconsin 2-0 red and jack pine seedlings had higher survival and faster growth when planted in deep furrows (8 to 9 inches) than when planted on top of the furrow slice (Wilde and Albert 1942). On soils with considerable duff or humus in the surface, growth of trees planted on the top of the furrow slice has exceeded that of trees planted in the bottom of the furrow.

If the jack pine that occupies the land is of good form, it can be left as a part of the new crop, the planting being done merely to reinforce the stocking.

Miscellaneous Silvicultural Problems

Except that it decomposes somewhat faster, red pine slash has the same fire-hazard characteristics as white pine slash. The methods of slash disposal used in the white pine type must be employed also in the red pine type (see p. 317).

The *European pine shoot moth* has been infesting red pine in some sections in recent years and has given evidence of becoming serious in some instances. In the absence of detailed information of the workings of this insect in the Lake states, the plan for control should follow that outlined for the oak region (p. 117).

Ips beetles attack red pine under the same conditions as in the white pine type (p. 317).

Control of rabbits in the manner outlined for the white pine type (see p. 318) is particularly important, because red pine recovers from injury slowly and thus, when injured, is put at a great disadvantage in competing with hardwoods.

JACK PINE TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest

Importance.
  Area—Major.
  Commercial Value—Low for saw timber, moderate for pulpwood.
Sites Occupied—Driest sands and sandy outwash plains, and, in northeast Minnesota, areas of rock outcrops (Committee Report 1932).

Associated Species.

Major—Jack pine (often pure), red pine, northern pin oak, quaking aspen, and paper birch.

Minor—Black spruce, white spruce.

Place in Succession—On driest sites it is a pioneer type, succeeded gradually by red pine or northern pin oak, or in northeast Minnesota by the white spruce–balsam fir–paper birch type.

Natural stands of jack pine are irregular, very dense over considerable area but very open on sites where severe fires have burned. Plantations that have a considerable acreage under 15 years old are mostly fully stocked. The natural stands are even-aged, and most of them are under 50 years old. Where the site has deteriorated severely from frequent fires, jack pine never attains large size and has scrubby form.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction in mature jack pine stands is variable in amount, distribution, and composition. Jack pine seedlings are limited to openings. Other species in the reproduction are chiefly those that originally occupy the site—red pine and eastern white pine on the dry sandy soils, balsam fir and black and white spruce on the moist or poorly drained soils. In general, advance reproduction is sparse.

Subsequent Reproduction. Contrary to earlier evidence (Sterrett 1920), jack pine is not a prolific reproducer on all sites; as a matter of fact, unless the conditions of the site are properly controlled, regeneration may be very poor. Jack pine is a moderately good seed producer, but little seed from standing trees reaches the ground. Not only are jack pine cones slow to open but the cones remain attached to the tree for several years. The seed in the cones retains its viability satisfactorily; there is little loss of viability in 3-year-old seed, and even 11-year-old cones contain a considerable number of viable seeds (Schantz-Hansen 1941). Consequently, mature forests have vast quantities of seed attached to the trees, awaiting release and a favorable seed bed in which to germinate. A sufficiently high temperature is the key to release of seed from the cones. Maximum release of seed occurs from cones that are nearest the ground in clearcut stands where the temperature is highest (Eyre and LeBarron 1944). Slash that is lopped places more cones in proximity to the ground than does untreated slash. Seed release is generally greater during the second year after cutting than during the first and is usually greatest during July and August, owing, undoubtedly, to the high temperatures during these months (LeBarron and Eyre 1939).

Seed-bed condition has a marked effect on the germination of jack pine seed. Germination is best on mineral soil, poorest on undisturbed duff, and intermediate on seed beds that have been burned or scarified (Eyre and LeBarron 1944, LeBarron and Eyre 1939, Zehngraff 1943). It is not affected significantly by the amount of overhead canopy. Survival of seedlings is affected by both seed-bed condition and over-

Photograph by U. S. Forest Service.

FIG. 56. A 30-year-old jack pine stand that is badly in need of thinning. This stand contains 26 cords of wood per acre, comprising 1472 live trees and 1098 dead trees per acre.

head canopy, being greatest on mineral soil and a site free of overhead canopy. Seedlings are very sensitive to shade and root competition.

The hardwoods reproduce vegetatively after cutting—aspen chiefly by suckering, the others by sprouting—and they therefore continue to be a part of the stand immediately after cutting.

Advance reproduction has an initial advantage over subsequent reproduction, but for only a short time, because jack pine seedlings and the hardwood suckers and sprouts grow rapidly from the start. When free of an overhead canopy, jack pine seedlings reach breast height in 4 to 6 years and a height of 20 feet in 18 years. Although such growth is fast enough to keep jack pine above other conifers, it

is not adequate to keep it ahead of the hardwoods. Jack pine's position and representation in the stand depend, therefore, on the abundance of competing hardwoods. On sites to which balsam fir and white spruce are well adapted, these species are likely to increase in number under any form of management, and, owing to their high tolerance, they can crowd out less tolerant species, such as jack pine.

Growth becomes very slow in dense stands, especially in overstocked stands (Fig. 56). Reduction of density of overstocked stands through thinning, which removes less than 50 per cent of the volume, may not increase growth during the first 5 years (Schantz-Hansen 1931*a*), but increased growth develops later, probably owing to improvement of crown size (Schantz-Hansen 1937*b*).

Windfall. Jack pine develops an extensive root system on deep sandy soils, but not so on the shallow stony soils of northeastern Minnesota. Windfall is serious only on the latter sites.

Economic Basis

Jack pine has its greatest value as pulpwood, for which purpose it can be utilized to a minimum diameter of 3 or 4 inches. Jack pine pulpwood does not command as high a price as spruce or fir, but in most sections it can be marketed readily. Cabin logs and mine timbers are other uses that absorb small quantities of jack pine. This species produces relatively inferior lumber.

Jack pine grows rapidly in early life, but growth culminates relatively soon—mean annual increment in cubic feet falling off at 40 years, and in board feet at 60 years (Wackerman, Zon, and Wilson 1929) (Fig. 56). On the better soils growth is fast enough to an advanced age in undamaged stands to justify a rotation of 70 or 80 years. This procedure is adequate to produce the various products that jack pine yields, since, even on the poorer sites, pulpwood can be produced in 55 years and saw logs and mine timbers in 60 to 70 years (Eyre and LeBarron 1944). Stands that are damaged by fire or decay cannot be maintained profitably at an age of more than 60 years.

Few data on the effect of thinning on growth are available. In one 30-year stand with a volume of 21 to 23 cords of wood per acre, growth during the first 5-year period after thinning, which removed 4 cords per acre, ranged from 1.1 to 1.5 cords as compared to 0.2 cord in an adjacent untreated stand.

Noncommercial thinnings can be rather expensive ($4.00 to $22.00 per acre) if postponed too long (Averell 1930, Schantz-Hansen 1931*a*).

Apparently such thinning can be done most economically in stands up to 10 feet tall (Eyre and LeBarron 1944). When thinning can be postponed until moderate amounts of pulpwood can be cut, a profit can generally be realized from the operation.

If disking to prepare the seed bed has been done after cutting, thus giving the added advantage of reduced fire hazard, cost has ranged from $4.25 to $5.95 per acre.

In a logging-cost study in a 48-year-old stand averaging 25 cords per acre of pulpwood, cost of producing pulpwood was lowest under clearcutting but only slightly higher under various degrees of thinning (Stott 1942). The author believes that, in stands that are sufficiently thrifty to respond well to thinning, increased growth after thinning might very likely increase the total wood production for the rotation enough to more than offset the higher cost of the partial cutting.

Application of Methods

The method of treating mature stands of the jack pine type must be determined by the quality of the site, the character of the stand with particular reference to the amount of advance reproduction, and the product that is the objective of management. On the best sites the production of red or white pine is probably the most profitable practice, in which case conversion to a new forest type should be the goal. On typical spruce sites conversion may be advisable also. If jack pine pulpwood crops are desired, the existing type must be maintained.

Clearcutting to Maintain the Type. The poor response of mature trees to release, their susceptibility to windfall, and the poor development of reproduction after partial cutting, make clearcutting the most desirable method of cutting for regeneration purposes. Cutting alone does not insure adequate reproduction. Soil preparation and slash treatment are equally essential. Soil scarification can be done to best advantage after the slash has been lopped and scattered. Slash treatment should follow soon after the timber products have been removed, except when cutting is done in midsummer, in which case slash treatment should be postponed until late summer. Slash treated late releases most of its seed the following year, and thus the loss of seedlings that might germinate in late summer after earlier treatment of slash is avoided.

An Athens-type disk reduced to the width of a tractor has given good results in soil scarification. An area must be disliked twice, the second time at right angles to the direction of the first disking, to

secure sufficient soil scarification for maximum regeneration (Eyre and LeBarron 1944).

Conversion to Another Type. The character and condition of the stand determine whether planting or cutting will effectively convert the stand from jack pine to red or white pine. Stands in which advance reproduction of white or red pine or spruce and fir is complete can be converted by clearcutting (except when white pine dominates the advance growth, in which case 20 per cent of the overstory should be left) (Schantz-Hansen 1937*a*, Young and Eyre 1937) followed by cultural operations. Stands in which there is no advance reproduction must be planted if they contain no seed-producing trees of the desired species, but if they contain seed-producing trees they can be cut by the selection method. Planting should follow cutting. The planting stock should be of the type recommended elsewhere for the species concerned, and the technic should be the same as outlined for other plantings. Cleanings must follow plantings.

Selection cutting in which the maximum amount of the jack pine is removed should be applied if reliance for conversion is to be placed on natural reproduction. Cleanings to free the desired species from jack pine and hardwoods must follow a few years after the reproduction cutting.

Thinning. Thinning must be a part of the silvicultural policy for existing pole stands as well as for stands that subsequently reach this stage of development. In very dense stands in which noncommercial thinning is desirable, such thinning should begin while the trees are under 10 feet tall. Commercial thinning can start after the thirtieth year, when pulpwood can be removed (Fig. 57). If thinning is begun at this time, several thinnings, each of which removes 20 to 30 per cent of the volume, can be applied. If frequent thinnings are not feasible, each should remove 40 to 50 per cent of the volume. Use of the principles suggested by Gevorkiantz, Rudolf, and Zehngraff (1943) and by MacAloney (1944) of removing the less thrifty, small-crowned, slow-growing trees will not only improve the general vigor of the stand but also assure rapid growth.

Planting. Reference has already been made to planting as a method of conversion of the type. Planting should also have a place in the restoration of denuded and very sparsely stocked land. On the bulk of this land jack pine 2-year-old seedlings should be used. Some red pine in mixture with jack pine is advisable on the better soils. If jack pine alone is planted, the spacing should be 4 by 6 feet; if red pine is used in mixture, the spacing should be 6 by 6 feet.

Direct seeding, first recommended to supplement planting on the better sites (Shirley 1937), has been found to be a particularly effective means of reforesting sites with a shallow water table, i.e., a permanent water table at a depth of 1.5 to 5.0 feet below the surface (Stoeckler and Sump 1940). Plowing of furrows is the most economical effective

Photograph by U. S. Forest Service.

FIG. 57. If thinnings can be frequent in jack pine stands, 20 to 30 per cent of the stand volume should be removed in each thinning. This 35-year-old jack pine stand on a good site has been thinned twice (the first thinning at 30 years), and each time approximately 4½ cords of wood were removed and 20 cords left.

means of site preparation. Sowing at a rate of ¼ to ½ pound per acre of jack pine seed with a Planet Jr. garden seeder between mid-April and early May has provided good seedling establishment at lower cost than planting.

Slash Disposal

Slash resulting from cutting of mature jack pine stands in Minnesota and Wisconsin is dense and, therefore, creates a high fire hazard. In Michigan the slash volume is relatively light, and the slash-fire hazard correspondingly lower. The slash decomposes fairly rapidly

so that at the end of 7 years it is no longer regarded as a serious risk (Zon and Cunningham 1931).

The silvicultural indispensability of slash in regeneration has been pointed out (see p. 325).

In view of the foregoing considerations, slash should be lopped immediately after cutting, and allowed to remain on the ground until the seed has been released from it. If disking is done after the slash is lopped, no further treatment of the slash is necessary. However, if the disking is done before cutting, partial piling and burning of slash after all seed is released from the cones may be advisable. In the more hazardous areas in Minnesota and Wisconsin a larger portion of the slash should be burned than elsewhere. Before the burning of the slash, especially intensive fire protection must be provided. After burning, it can be somewhat less stringent.

Disease and Insect Problems

The *spruce budworm* was reported in 1935 (Graham) as a serious pest on open-grown jack pine because such trees produce a large quantity of staminate flowers, the food most favorable to high survival of budworm larvae. In 1938 it was found to be fairly common in mature stands of jack pine in northern Minnesota and adjacent Ontario. Later it was reported that trees in the suppressed and intermediate crown classes and any trees of poor vigor produce staminate flowers abundantly (Hodson and Zehngraff 1946). Partial or complete defoliation of the infested tree may cause stag-headedness, occasionally reduced seed production, and sometimes death. The attack is most likely to be fatal when the budworm works in conjunction with the jack pine sawfly—the budworm consuming the new foliage, the sawfly the old foliage. Infestation of the "wolf trees" may lead to infestation of near-by reproduction. Control is dependent on the removal of trees that are large producers of staminate flowers in the vicinity of reproduction and the maintenance of fully stocked, young stands (they should be dense enough to close in 10 to 15 years, a condition which the 4 by 6 foot spacing for plantations should insure).

The *jack pine tipmoth,* which attacks the terminal bud and stem of the current year's growth, causes severe deformity and loss of height growth when the attack is recurrent. The damage it has produced is spotty, and, like the spruce budworm and sawfly, this insect is a serious menace only when working in conjunction with another pest.

An unidentified scale insect attacks jack pine and kills occasional trees. No practical control measures for these pests have been discovered.

Red ring rot infects many jack pines over 60 years old, particularly damaged trees. The decay progresses rather rapidly. Prevention of injury to the trees and adjustment of the rotation are practical control measures.

Control of Animal Damage

If rabbits are a menace to jack pine seedlings, as they are where shrubs are abundant, control measures such as are recommended for the white pine type are necessary. Control of deer in the manner previously outlined is essential also (see p. 318). Domestic livestock presents no problem.

ASPEN AND PAPER BIRCH TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. The aspen type is a major one, occupying, according to the best estimates, nearly 21,000,000 acres or 37 per cent of the total forest area of the region. The paper birch type has only a small area, but it is included here because it presents the same problems as the aspen type. They differ primarily in composition. The discussion refers specifically to the aspen type but applies equally well to the paper birch type, except for the statements on composition.

Importance.
- Area—Major, occupying one-third of the forest area of the Lake states.
- Commercial Value—Low, often none.

Sites Occupied—Practically any site except the driest sands and the wettest swamps.

Associated Species.
- Major—Quaking aspen, sometimes pure, bigtooth aspen, balsam poplar, paper birch, pin cherry.
- Minor—Variable, consisting of species that originally occupied the site.

Place in Succession—A short-lived temporary type following fire, usually succeeded by white pine, one of the northern hardwoods, or one of the spruce types (Committee Report 1932). In Minnesota it is not so readily replaced as elsewhere.

The stands are even-aged and mostly under 30 years old. In some sections extensive areas are from 40 to 50 years old. Although well stocked on small tracts, the stands on large areas are 40 to 50 per cent understocked. Stands over 40 years old are particularly thin because deterioration has already set in. From 16 to 85 per cent of the trees over 14 inches d.b.h. are so defective from heart rot that they are useless commercially.

Classified according to their occurrence by site classes, the distribution of aspen stands is as follows: 15 per cent on good sites, 54 per cent on medium sites, and 31 per cent on poor sites.

Stand Regeneration and Development. *Advance Reproduction.* Advance growth, made up of reproduction and/or saplings, varies greatly in amount and in composition from stand to stand. In general, it is sparse and irregularly distributed and is composed of species that originally occupied the site: eastern white pine, red pine, balsam fir, and sugar maple are the dominant species, and some witch hazel and alder occurring on occasional sites. Quaking aspen or paper birch is rarely among the advance reproduction. The occurrence of reproduction in the uncut stands is usually related to the presence of seed trees near by (Kittredge and Gevorkiantz 1929), at least four per acre being necessary for a good stand of reproduction. However, even in the presence of seed trees advance growth may be deficient, owing apparently to the unfavorable seed bed created by heavy leaf litter and to the intense competition, which reduces soil moisture and light intensity below that required by the conifers for survival and growth (Shirley 1941). Even though the conifer seedlings may survive for some time, deer, rabbits, and other animals may eventually destroy them.

Subsequent Reproduction. Unless seed trees of species other than quaking aspen or paper birch are on or adjacent to a stand, subsequent reproduction of such species cannot be expected to become established after any type of cutting. Cutting is, however, followed by aspen sucker reproduction and paper birch sprout reproduction. The amount of suckering varies with the time of year that cutting is performed. Winter cutting produces the most abundant stand of suckers, spring cutting a less dense stand, and summer cutting the lightest stand. Suckers developing after summer cutting suffer the greatest damage from frost during the first winter and they attain less height the first year than suckers developing after winter or spring cutting. Girdling of the trees in the stand, on the other hand, may be followed by very few aspen suckers.

Effect of Competition. If an aspen stand is left untreated, there is no immediate change in its composition. What changes take place ultimately depend on the species making up the advance growth and the density of the overstory. Such tolerant species as balsam fir, spruces, and sugar maple are likely to have a high percentage of survival, but their growth is very slow.[3] Less tolerant species have low survival, poor form, and poor growth.[4] Some of the advance growth survives to the end of the aspen's life, and when the aspen dies the site is occupied partially by the species composing this advance growth. In not more than 10 to 20 per cent of the area of aspen type, however, does natural conversion result in a satisfactory timber stand; and the process takes 50 to 90 years, depending on the site (Kittredge and Gevorkiantz 1929).

In untreated stands lacking advance growth no great change occurs in the composition of the stand unless seed trees are near by. Underplanting in these stands is invariably unsuccessful except in openings, where some trees survive.

If an aspen stand is cut, the advance growth is released. How soon and to what extent its growth will increase depends on the ability of the advance growth to recover. Tolerant species usually show the best recovery. Aspen suckers develop soon after cutting, and since they grow rapidly they usually overtake and overtop the advance growth. Since the quantity of suckers and their rate of growth are affected by the time of year the cutting of aspen occurs, the degree of competition they offer the advance growth also depends in part on when the aspen is cut. Quality of site is a factor in competition, for it strongly influences the growth of aspen (as well as other species). Without subsequent treatment, the aspen is likely to dominate the stand within 10 years after cutting.

Where advance growth is absent but an understory is established by planting, the planted trees will have low survival in cut-over stands, unless they are released from the aspen suckers not later than the second year after being planted and every year thereafter for 3 to 5 years. Released planted red pine has grown three and one-half times

[3] In a 45-year-old quaking aspen stand in Michigan the aspen had an average d.b.h. of 5.2 inches and a height of 50 feet, whereas white spruce and balsam fir had an average d.b.h. of 1.8 and 1.9 inches, respectively, and an average height of 14 feet (Westveld 1933*b*).

[4] In Minnesota, Eyre (1933*b*) reports nearly as many dead as live pines in an understory. In a 33-year-old aspen stand he found that aspen and birch were 40 feet tall and pine, then 25 years old, 19 feet tall.

as fast as unreleased trees in 5 years when the release was complete, and one and one-half times as fast when partially released (Eyre 1933*b*).

Windfall. Aspen and paper birch are not particularly susceptible to windfall, but they are highly susceptible to windbreakage, especially when they reach maturity. At that time their boles are seriously weakened by rot that is extensive.

Economic Basis

The market for aspen has expanded greatly, particularly since 1935, but, even so, in 1946 less than 40 per cent of the estimated annual growth was being harvested. Increased use for pulpwood is particularly evident: in 1935 only 4 per cent of the wood employed for pulp in this region was aspen, whereas in 1944 the percentage was 18.4. Currently aspen is used in smaller quantity for excelsior, wall and building board, lumber, and occasionally veneer. Markets for aspen vary considerably; the best ones are in Wisconsin. In 1945 it was estimated that there were 6,500,000 board feet of saw timber in aspens 9 inches d.b.h. and larger, 17,000,000 cords of high-grade pulpwood, and 26,000,000 cords of wood not suitable for present-day use.

Only on the best sites (hardwood soils, site index 70 or higher) can aspen be grown to saw-log size. On such sites trees of saw-log size can be produced in 50 to 60 years. On medium sites, a rotation of 40 to 50 years produces small logs and pulpwood. After 50 years deterioration of aspen is fast. Poor sites will not yield good pulpwood before decay becomes extensive. Smaller wood suitable for conversion into wall board can be produced in 25 years on such sites. When located near a market for such products, stands on the poor sites can be profitable. Schantz-Hansen (1945*b*) reports a net return per acre per year of $0.71 on a 25-year rotation based on 1942 prices. He estimates that net return would have been $1.42 at 1945 prices.

Nonrevenue thinning appears practicable in aspen stands. Ten years after a noncommercial thinning in a 13-year-old stand which gave a spacing of 8 by 9 feet, the thinned stand supported a volume of 17.5 cords and the unthinned stand 7.37 cords per acre. Average diameter of the trees was 4.9 and 3.0 inches, respectively.

It is obvious from the manner in which untreated aspen stands develop (see p. 334) that even if advance growth is present this material rarely develops into merchantable size in sufficient quantity, if any, to yield a profitable crop. Even where the advance growth does survive in considerable quantity, as is sometimes the case with spruce

and fir, the value of the crop may be less than one-third as much as it might have been if the overstory had not interfered.[5] Obviously an investment of $1.50 to $5.00 in cleanings yields high returns.

Conversion of aspen stands to conifers by planting is very expensive: it was reported in 1941 as costing $17.00 per acre for site preparation and planting and $13.00 per acre for subsequent weeding and overstory removal (Shirley 1941). More recent work on cleaning indicates that cost of this operation can be reduced by proper seasonal application (Stoeckler 1947). Returns are too low on the large investment to be attractive to landowners.

Application of Methods

The method of handling either the aspen or paper birch type must be determined by the species the owner wishes to produce (which, for aspen, is determined by the market), the site quality, the amount of defect present, and the presence or absence of advance growth. Except in those few localities where aspen can be marketed advantageously it will be best to produce some species, other than aspen, that is well adapted to the site. This implies conversion of the type.

Perpetuating the Type. On good sites (site index 70 or more) and on medium sites situated near satisfactory markets for aspen, the aspen type should be perpetuated by clearcutting. Regeneration will be simplified when cutting can be done between October and April. When cutting must be done in summer, the cutting should be followed 2 or 3 years later by disking. All trees including the culls and other unmerchantable trees should be removed from the stand.

Noncommercial thinning of young stands is desirable before the twentieth year. A spacing between trees of 8 to 9 feet on good sites and 7 feet on medium sites is the best yet developed. Low thinning that removes the smaller-crowned, least vigorous trees is recommended (Gevorkiantz, Rudolf, and Zehngraff 1943). On good sites the nonrevenue thinning should be followed by pulpwood thinnings at 5- to 10-year intervals. On medium sites two pulpwood thinnings separated by intervals of 7 to 10 years bring the stand to maturity. Many of the stands on medium sites are better suited to the production of other species and should, therefore, be cut accordingly.

Conversion by Cutting. The method of accomplishing conversion must be based primarily on the presence or absence of advance growth

[5] The value of a 45-year-old aspen stand with a spruce and fir understory was estimated by Westveld (1933*b*) to be $30 as against $100 for the same-aged stand of spruce and fir grown free of an overstory.

of desirable species and on the site quality. Cutting can be the method in aspen stands originally occupied by white pine and/or red pine (site index about 63) and now supporting adequate advance growth of desirable conifers for a new stand. All the quaking aspen and paper birch should be removed unless the advance growth is white pine or very small reproduction (under 1 foot) of any species, in which case 20 per cent of the overstory should be left for protection. Girdling is preferable to cutting of the aspen, because suckering is less prolific after girdling, and thus additional treatment is unnecessary. A second cutting 3 or 4 years after the first is often required.

Conversion by Planting and Cutting. Aspen stands growing on poor and some of the medium sites and lacking desirable advance conifer growth should be converted to conifers by planting and cutting. Conversion can be accomplished most effectively where the aspen is small or sparse, where it has just been cut, and where the sites are not in the vicinity of swamps used by deer as winter yarding grounds. If the overstory has a density of more than 50 per cent, the first step in conversion is to reduce, through cutting or girdling, the stand density to not more than 50 per cent. In preparation for planting, either furrows should be plowed or spots 20 inches square should be scalped (Shirley 1941). Undergrowth, if dense, should be opened. Trees should be planted by the deep hole method.

On poor sites either 1-1 jack pine or 1-2, 2-1, or 2-2 red pine, and on medium sites either 2-2 white pine or 2-2 or 2-3 white spruce should be chosen. Subsequent treatment of these stands must include cleanings and removal of the overstory. The first cleaning should be made 2 or 3 years after the planting is done. If the cleaning is made betweeen June and August—the ideal time is shortly after maximum leaf development—a single cleaning may be sufficient (Stoeckler 1947). Otherwise, subsequent cleanings are usually necessary. Removal of the overstory aspen should be done when the conifers have reached heights of 4 to 6 feet (Shirley 1941). Removal should be gradual; the procedure is cutting the aspen by narrow strips. Animal control, as outlined on p. 318, is absolutely necessary.

Slash Disposal

The volume of slash in cut-over aspen or paper birch stands varies widely with the site (which influences the volume of the stand) and the method of cutting. The immediate hazards that the slash creates, therefore, differ a great deal. In any case the slash has low inflamma-

bility and decomposes so rapidly that the hazard is of short duration. Decomposition of the slash is complete in 4 to 5 years, and the hazard is nil at that time.

Because of the low degree and shortness of the fire hazard, intensive protection for 3 or 4 years can be substituted for disposal of the slash, except where other factors create a very high fire hazard, in which case partial disposal, like that applied in the northern hardwoods types (see p. 312), is advisable.

Disease and Insect Problems

Rot is an important factor in limiting the merchantability of aspen, especially on the poor sites (site indices under 50). The significance of this situation has been discussed previously (p. 335). Rot is generally established by the thirtieth or fortieth year, and by the fiftieth year annual loss of merchantable material by rot often exceeds the growth of new wood (Kittredge and Gevorkiantz 1929). By 70 years, more than 20 per cent of the wood volume may be rotted. Regulation of the rotation or conversion to another type are the only practical controls.

Hypoxylon canker is often severe in pure young stands, in which it may cause the death of many trees. No control for the disease has been developed.

The *forest tent caterpillar,* a defoliator, is responsible for complete defoliation of aspen during occasional years. Unless the defoliation is repeated for several years, in which case some trees are killed, temporary reduction in growth is the chief result.

Larvae of the caterpillar are susceptible to DDT, but the practicability of its use has not been demonstrated.

The *poplar borer*, a primary insect that does damage on all sites and to all classes of trees, reduces timber quality and, by weakening the wood, may contribute to windbreakage. No control is known.

Control of Animal and Logging Damage

Control of animal damage must be concerned chiefly with control of rabbit and deer populations, as outlined on p. 318.

Logging presents no special problems except in stands where the overstory is removed from a well-stocked understory by cutting. In this case unusual care in the felling and removal of the overstory must be exercised to protect the understory trees.

BLACK SPRUCE TYPE

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of Forest

Importance.
  Area—Major, especially in Minnesota.
  Commercial Value—Moderate.
Sites Occupied—Poorly drained, acid muck, and peat swamps.
Associated Species.
  Major—Black spruce (sometimes pure), northern white-cedar, balsam fir (Committee Report 1932).
  Minor—Tamarack, black ash, red maple, paper birch. Varies with character of soil, freedom of drainage, and thickness of sphagnum moss.
Place in Succession—Probably subclimax.

The black spruce type occurs both as an even- and an uneven-aged stand. Owing to the generally high density of the even-aged stands, there is a wide variation in the size of the individual trees, giving these stands an uneven-aged appearance. Cutting has reduced the area of uncut forest to a small acreage. Most of the cut-over area supports a sparsely stocked stand similar in composition to the original stand, except that the hardwoods are more numerous because they are rarely cut.

The original stands yield 5 to 15 cords of pulpwood per acre. The ground cover in well-stocked stands is sparse, whereas on cut-over lands it is generally heavy, consisting chiefly of Labrador tea, sphagnum moss, and leather leaf.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction is reported to be generally abundant in mature stands in Minnesota, a contrast to conditions in Michigan, where advance reproduction is sparse except in openings. Some of the reproduction, particularly on sites with a thick ground cover of sphagnum moss, is layers. In 1917, Kenety attributed the scarcity of black spruce seedling reproduction in swamps to the low temperature of the seed bed during the growing season, the saturated condition of the soil, and the lack of mineral soil and sunlight. There is no recent evidence to contradict his conclusions.

Subsequent Reproduction. The requirements for satisfactory regeneration of black spruce have not been established by comprehensive

research. This is evidenced by the fact that in an experiment in Minnesota abundant black spruce reproduction became established both in uncut strips and in clearcut strips which were 75 feet wide (Schantz-Hansen 1931*b*). It appears from scattered reports that the condition

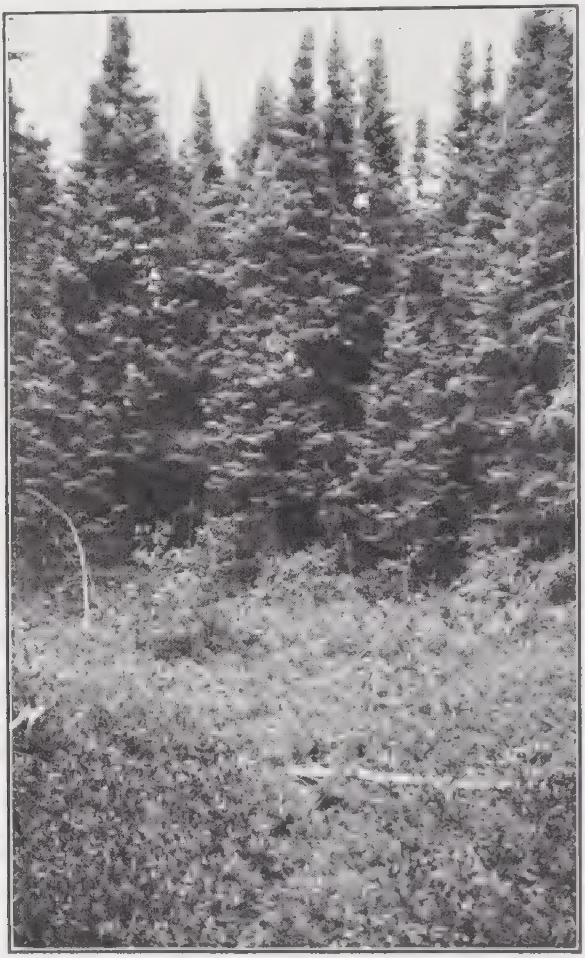

FIG. 58. A 35-year-old stand of black spruce. Stands that were dense often suffer severe windfall if cut selectively.

of the seed bed is an important factor in regeneration. On mineral soil or on seed beds where litter, shrubs, mosses, or slash have been disposed of, establishment of seedlings is abundant, but where vegetation, litter, or slash are not treated reproduction is sparse.

Wherever northern white-cedar occurs in the stands on sites to which it is well adapted, it apparently reproduces with ease after cutting, if there is a source of seed.

Wherever the hardwoods are cut, they reproduce readily by sprouting from the stumps. If they are not cut they reproduce from seed. Quaking aspen, bigtooth aspen, and balsam poplar will seed in on cut-over land to which they are near.

Competition. The hardwood reproduction grows much faster than the black spruce or white-cedar reproduction. The difference in growth is especially pronounced if the hardwoods are of sprout or sucker origin.

Fig. 59. A fairly open-grown stand that was cut selectively 7 years previously No windfall has occurred.

The spruce and cedar are quickly overtopped and their growth is seriously retarded as the suppression continues. In many stands there are few, if any, hardwoods. In such stands the spruce and cedar compete chiefly with each other, in which case neither one is likely to be suppressed by the other. The spruce is very tolerant; thus its survival is high under intense competition, and upon release from suppression it soon grows at a normal rate. Cedar is less tolerant, but it survives reasonably well when suppressed.

Windfall. Black spruce stands are very susceptible to windfall under certain conditions—in very dense stands, in released understories, or on very wet sites (Fig. 58). Spotted windfall frequently occurs in uncut stands under these conditions, and in partially cut stands it is more general. Even-aged stands are reported to suffer more damage from windfall than uneven-aged stands (Bowman 1944). Stands that are cut lightly (those from which less than 40 per cent

of the stand volume is removed) suffer less from windfall than stands that are cut more heavily (LeBarron 1945). In stands of moderate density, windfall is not so serious, even in partially cut stands (see Fig. 59), owing apparently to a more extensively developed root system.

Economic Basis

The black spruce and balsam fir, suitable chiefly for pulpwood, and the northern white-cedar, suitable chiefly for poles, posts, and shingles, are the most valuable species of the black spruce type. The hardwoods have little commercial value except for fuelwood, for which there is little market.

The growth of black spruce is slow, even on the best sites. In Minnesota, yield of merchantable wood was 24, 36, and 47 cords per acre for poor, medium, and good sites, respectively, at 100 years (Fox and Kruse 1939). This is an annual growth of less than one-half cord on the best sites. LeBarron (1945) reports growth of 0.54 cord per acre per year over a 6-year period following selection cutting that removed 40 per cent of the stand volume. Bowman (1944) reports that mean annual growth declines at 55 to 60 years in even-aged stands. At 60 years mean annual growth per acre ranges from 0.06 cords of peeled pulpwood in trees 4 inches d.b.h. and over for site index 20 to 0.48 cord for site index 60. Uneven-aged stands make somewhat better growth than even-aged stands. On fair to good sites growth of black spruce after release was 2.2 inches in diameter in 20 years; on poor to very poor sites growth was 1.7 inches in diameter in 20 years. Growth is stimulated greatly—61 to 138 per cent—by artificial drainage of very wet sites, but to date the cost of drainage has been too high to justify its use (Zon and Averell 1929). On the best sites pulpwood can probably be produced in 60 years, but on the average sites the rotation must be 80 to 100 years or longer. The poorest sites never yield trees of merchantable size.

Application of Methods

Clearcutting on strips not over 75 feet wide (preferably narrower) is recommended for mature stands occupying sites of high windfall danger and mature stands composed chiefly of trees of merchantable size. The strips should run preferably at right angles to the prevailing winds. Cleanings must follow if hardwood reproduction is abundant.

In some mature stands—those containing many trees too small for pulpwood—selection cutting is the only feasible method, irrespective

of the windfall danger; in others—those on sites with a low windfall hazard—selection cutting is advantageous, because thereby it is possible to leave trees somewhat above the marginal size for increased growth, which usually follows release (Fig. 59). Since light cutting involving not more than 40 per cent of the pulpwood volume (trees 6 inches d.b.h. and over) minimizes windfall and provides the best growth, cutting should not exceed this amount. It is preferable to keep the cut at not more than 30 per cent of the total volume.

Thinning of dense stands is certainly desirable silviculturally; but since, to get the greatest benefit, at least the first thinning and possibly the second should be made before the trees reach merchantable size, it appears that thinning is not practicable because of the cost factor, unless it is done before the trees attain a diameter of 2 inches.

There is a place for planting on cut-over lands that are understocked, but a technic has not been developed. Therefore, no recommendations are made here.

Miscellaneous Silvicultural Problems

The statements that follow are based on personal observations. Slash volume on cut-over lands is moderate. It varies with the closeness of utilization. Since utilization is commonly down to a 3-inch top or lower, slash volume is now much less than formerly. The needles have dropped from the limbs but decomposition of the wood has barely started in 2 or 3 years. Decay of the slash is relatively slow and is not complete in less than 12 years. In spite of this slowness the slash creates only a moderate fire hazard on most sites, because of their wetness. On some of the drier sites in Minnesota, however, the slash creates a serious risk. Although slash interferes with regeneration, reproduction usually is sufficiently abundant on slash-covered areas to provide adequate stocking.

Partial disposal by piling and burning or swamper burning on strips supplemented by intensive fire protection seems adequate to curb the fire hazard.

The same insects and diseases that attack the white spruce–balsam fir–paper birch type damage the black spruce type. For a full discussion see p. 346.

So far as is known little or no damage is done by animals.

Greater care in logging selectively cut stands than is ordinarily used is essential if cut-over lands are to be kept productive. Fewer, nar-

rower logging roads can do much to reduce the worst logging damage, but greater care in felling is also necessary (Westveld 1933*a*).

WHITE SPRUCE–BALSAM FIR–PAPER BIRCH TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest

Importance.
- Area—Major.
- Commercial Value—High.

Sites Occupied—Cold upland loamy soils of high moisture content.

Associated Species.
- Major—White spruce, balsam fir, paper birch.
- Minor—Any or all the following: jack pine, quaking aspen, black spruce, eastern white pine, northern white-cedar, sugar maple, green ash, red maple, yellow birch (Committee Report 1932).

Place in Succession—Probably a climax type. Fire causes a reversion to an aspen or paper birch type.

Both even- and uneven-aged stands make up the white spruce–balsam fir–paper birch type. They vary widely in stocking, but they are generally understocked. Cut-over land, constituting a large portion of this type, supports a scattered stand of small spruce and fir and an overhead canopy of low-value hardwoods. Vegetation is sparse and the needle and litter layer thick in uncut stands. Herbaceous vegetation is generally great in heavily cut stands, ferns being dominant.

Stand Regeneration and Development. Advance reproduction, in which balsam fir predominates, is generally sparse in mature forests. It is most abundant in openings. In those stands that do support a good stocking of advance growth, utter disregard in logging has resulted in the destruction of much of it—57.7 to 95.7 per cent (Westveld 1933*a*). The advance reproduction must be supplemented by subsequent reproduction if cut-over land is to be well stocked.

Since the regeneration of this type has been studied in only a limited, superficial way, only a few general observations will be made. Any kind of cutting which includes the hardwoods is followed by prolific regeneration of the hardwoods—suckers from the quaking aspen and sprouts from the others. Regeneration of spruce and fir is absolutely

dependent on a seed supply. For unknown reasons balsam fir nearly always reproduces more generously than white spruce. Both seem to reproduce better in mineral soil than in a seed bed covered by a thick layer of needles or occupied by heavy vegetation, as evidenced in part in one instance by eleven and five times as many white spruce and balsam fir 1-year seedlings, respectively, on mineral soil as in heavy vegetation (Robbins 1930). Since vegetation, particularly ferns, often establishes a fairly dense cover within a year or two after cutting, the site becomes progressively less favorable for the establishment of spruce and fir seedlings.

Since the hardwood reproduction makes rapid growth, it has a distinct advantage over spruce and fir reproduction. It soon overtops the latter, the growth of which is quickly impeded thereby. The ultimate character of such a stand is depicted by many aspen stands that support a spruce and fir understory (see p. 334).

Windfall. Balsam fir and white spruce, because of their shallow root systems, are very susceptible to windfall. On the wetter and the rocky sites, conditions favorable to windfall are accentuated, and on such sites windthrown trees are numerous even in uncut stands. The older balsam firs, often highly defective with rot, suffer windbreakage.

Economic Basis

White spruce is the most valuable species, primarily for pulpwood. Balsam fir is readily marketable as pulpwood in nearly all sections, but its sale value is only one-half to two-thirds that of white spruce. Any of the other conifers can be marketed without difficulty. Their quality is relatively low because their development is inferior on these sites. The hardwoods have little or no commercial value.

In a free position, balsam fir grows faster than white spruce. Release of crowded trees results in slightly more rapid growth of white spruce than of balsam fir (Bowman 1944).

Application of Methods

Cutting must take cognizance of the windfall hazard and the general deficiency of advance reproduction.

Partial cutting—selection cutting in uneven-aged stands, shelterwood cutting in even-aged mature stands—in the author's opinion seems advisable where advance reproduction is deficient. The first cutting by either method should remove 20 to 40 per cent of the merchantable volume of the stand (Day 1942). Balsam fir should be cut more closely than white spruce, and the larger seed-producing trees

of the former should by all means be removed. A cutting cycle of 15 to 25 years should be feasible under the selection system. The second or final removal cutting under the shelterwood method should be made 5 to 10 years after the first cutting, the exact time depending on the time required for successful establishment of reproduction. Hardwoods should be cut or girdled at the time of the first cutting. Soil preparation (probably by hand since disking would not be practical) is probably advisable, although there is little evidence to support this suggestion.

Clearcutting is recommended wherever advance reproduction is present in a mature stand over an extensive area in sufficient quantity to provide a fully stocked new stand. If hardwoods are numerous they should be cut or girdled; if not, their retention for protection is advisable.

A cleaning is in order within 10 years after the reproduction cutting in any stand in which hardwood reproduction is abundant. If it can be postponed without serious harm to the spruce and fir seedlings until 8 or 10 years after the reproduction cutting, two cleanings, or, in some cases, only one, will be all that is required. However, where hardwood reproduction is particularly dense, the first cleaning must be made not later than the fifth year.

There is a limited acreage of denuded and abandoned farm land on which planting is necessary. White spruce transplanted stock (2-1 for open sites, 2-2 for brushy sites) is recommended. Spring planting is preferable to fall planting on most of the sites because of the frost-heaving hazard; otherwise, the planting technic can be the same as that used on pine sites.

Miscellaneous Silvicultural Problems

Slash disposal should be the same as for the black spruce type (p. 343).

Rot, particularly yellow stringy butt rot and balsam butt rot and red top rot in the upper part of the bole, is prevalent in balsam firs over 40 years old (60 per cent of the trees may be infected at 70 years). In trees older than this the volume of rot increases with age. Most of the butt rot (93.6 per cent) enters through the roots; most of the top rot (91.2 per cent) enters through dead or broken branch stubs. The volume of rot increases from 5.3 per cent of the tree's volume at 60 years to 10.7 per cent at 80 years, and 41.0 per cent at 150 years. Actual cull is 70 to 150 per cent above these figures (Kaufert 1935).

White spruce is attacked by rot-producing fungi; but it is not nearly so susceptible to infection as balsam fir, and the rot is proportionately less.

The spruce budworm attacks both the balsam fir and the white spruce, the former being much more susceptible. There is, however, no record of recent epidemic attacks in the Lake states.

The adoption of a rotation of 80 years or preferably less (which is in line with pulpwood production, see p. 345) and the cutting of balsam fir to a lower diameter than white spruce to discourage its propagation are recommended as control measures.

NORTHERN WHITE-CEDAR TYPE

The northern white-cedar type occupies a fairly large area and has high commercial value because of the predominance of cedar. The discussion of this type will be abbreviated because there is little specific information on it. It is both an upland and swamp type, occurring on limestone uplands and poorly drained peats and mucks that are not strongly acid (Committee Report 1932). Tamarack, balsam fir, black spruce, eastern white pine, and hemlock are minor associates of the cedar. The mature cedars usually are very defective from rot. The uncut stands are dense, whereas cut-over stands are generally fairly well stocked because of the large quantity of advance growth of reproduction and/or sapling size in the stands, much of which survives logging. The general abundance of advance growth, the apparent ease with which cedar seedlings become established after cutting if seed is available, and the sparseness of hardwoods, which relieves the cedar seedlings from competition with them, make simple management measures fairly effective.

Except in overmature stands where the large amount of defect makes clearcutting advisable, selection cutting is recommended. Ordinarily trees below 6 inches d.b.h. cannot be marketed, and so there is a definite diameter-limit restriction. Large defective cedars should usually be cut—except when needed for seed—even though they contain little merchantable material, because if left they occupy valuable growing space. The cedar should be favored in the new crop.

Thinning shows the prospect of being a profitable practice on the better-drained sites.

Slash disposal should follow the same plan as in the black spruce type.

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10 • *Douglas-Fir Region*

DESCRIPTION AND HISTORY

Location and Landownership

The Douglas-fir region of Oregon and Washington consists of that part of the two states west of the summit of the Cascade Range (Fig. 1). The region has a total land area of 35,118,720 acres, of which 29,147,034 acres, or 82 per cent, is forest land.[1]

The ownership of commercial forest land available for timber management is divided as follows: federal and Indian (mostly national forest), 10,199,670 acres; state, 1,557,380 acres; county and municipal, 1,059,300 acres; private, 13,210,100 acres.

The 29,000,000 acres of forest land, in 1947, supported a timber stand of over 426,000,000,000 board feet. Most of the land area was originally covered with timber. Land clearing for agriculture and the exploitation of the forest for commercial purposes have broken the continuity of the timber stand.

Physiographic Features

The summit of the Cascade Range separates this region from the northwest ponderosa pine region. The main mountain range slopes gradually to the west and stands from 4000 to 7000 feet above sea level. Numerous peaks project to a height of more than 10,000 feet. The mountain slopes are steep, and the surface is irregular and rugged (Fenneman 1930). The highest peak in the region is Mt. Rainier, which has an elevation of 14,408 feet.

The Calapooyo Mountains, a western spur of the Cascades at the south end of the Willamette Valley in southern Oregon, connect the Cascade Range to the Oregon Coast Range. The Oregon Coast Range

[1] These statistics and others that follow, as well as certain unreferenced statements, are taken from various mimeographed reports of the Pacific Northwest Forest Experiment Station, Portland, Oregon.

is continuous from the Columbia River to southern Oregon, where it joins the Klamath Mountains. It is a relatively low range, its crest lying chiefly between 1700 and 3000 feet.

The Olympic Mountains in western Washington, occupying approximately 4000 square miles and terminating in Mt. Olympus with an elevation of 7915 feet, are isolated from other mountain ranges. The bulk of the range lies below 5000 feet.

Between the Cascade Mountains on the east and the Oregon Coast Range and the Olympic Mountains on the west lies an extensive area of rolling to rugged hills, occupied by the Willamette Valley and Puget Sound.

A variety of soils are found in the Douglas-fir region. These include gravels, sands, heavy clays, loams, and volcanic ash. The sands and gravels occur most extensively in the vicinity of Puget Sound. The volcanic ash occurs at the higher altitudes in the vicinity of old volcanoes, and the clays and loams are quite generally distributed throughout the region. Many of the soils are characterized by an abundance of rock in mixture.

The Columbia River, which separates the states of Oregon and Washington, is the largest stream in the Douglas-fir region. The Willamette River, draining much of the central and eastern part of the region lying in Oregon, enters the Columbia near Portland, Oregon. The Umpqua River is the most important drainage system south of the Willamette Valley. Numerous streams flowing in a westerly direction originate in the west slopes of the Oregon Coast Range and find outlets in the Pacific Ocean. Most of the streams in southern Washington flow south into the Columbia River.

Climatic Features

The climate of the Douglas-fir region is humid and, in general, favorable to vegetative growth. It varies greatly in different sections, being affected largely by distance from the Pacific Ocean, latitude, and altitude. These factors have a pronounced effect on precipitation, relative humidity, temperature, length of growing season, wind movement, and lightning.

The mean annual precipitation varies from more than 151 inches at Glenora, Oregon, to slightly over 20 inches at several stations on the north slopes of the Olympic Mountains in Washington (Weather Bureau 1926). The range in precipitation for most of the region is between 40 and 60 inches per year. Generally speaking, the precipi-

tation is greatest along the coast, gradually decreasing inland until the higher altitudes of the Cascades are reached, where it increases. The precipitation is decidedly seasonal in distribution. The summer is dry, the mean monthly precipitation during July and August being approximately 1 inch. The rainy season occurs during winter, from November through February, when rain falls almost daily.

Except at the high altitudes, practically all the precipitation is in the form of rain. Only at elevations above 1500 feet does snow lie on the ground for extended periods.

The atmosphere is humid at all seasons of the year except for short spells during summer when the relative humidity may fall below 30 per cent. From April to September the relative humidity is usually between 50 and 60 per cent during the driest part of the day; during the remainder of the year it is more often between 80 and 90 per cent.

Temperatures are mild throughout the year. Below an altitude of 1500 feet, freezing temperatures are rare and of short duration. With the exception of the high mountains, the temperature varies from an average minimum of 30° F. during winter to an average maximum of 52° F. during summer. The average temperature during the growing season is 56° F. Occasional midsummer temperatures of more than 100° F. and occasional winter temperatures of zero or lower have been recorded. Most of the region has a period of 6 to 8 months free of killing frosts.

Storms accompanied by lightning and little precipitation are of common occurrence in some sections. Lightning causes 40 and 3 per cent, respectively, of the total number of fires on national forest and privately owned land.

The prevailing winds during summer are from the north and northwest and during the winter from the south and southwest. Occasional dry winds from the east cause high temperature in summer and low temperature in winter. The wind is most likely to reach destructive force in winter, particularly along the seaboard. The worst storm on record occurred on the Olympic Peninsula on January 29, 1921, when the wind attained a recorded velocity of over 140 miles per hour before the recording instrument was wrecked (Boyce 1929). Exclusive of these severe storms, the wind velocity varies from 5 to 15 miles per hour.

Development of Lumbering

The first sawmill in the region was established in 1827 near Fort Vancouver (Brandstrom 1933). Not until 1845, however, did the first

commercial enterprise in lumbering begin, when a sawmill was established on Puget Sound (Forest Service 1920). The gold rush in 1849 served as an impetus to increased cutting in the Douglas-fir region. Before 1850, sawmills had capacities of 2000 to 10,000 board feet per day, but, after this date, some mills had daily capacities of 100,000 board feet. The extension of transcontinental railroads into the west was a decided boon to the lumber industry of the Douglas-fir region in that it created a market for more material and provided a means of transportation for lumber to many previously inaccessible parts of the United States. High freight rates on lumber at first restricted rapid expansion of the lumber industry. After the lowering of freight rates on eastern lumber shipments in 1894, the real development of the lumber industry began. Large-scale operations developed most rapidly in Washington. By 1905 this state was a leader in lumber production, the bulk of the cut coming from that part of the state lying in the Douglas-fir region. Since then this state has been far in the lead in lumber production, with the exception of one year, 1914.

Although cutting in Oregon has never been as extensive as in Washington, the former state has been one of the leaders in lumber production for a number of years. Although there has been a gradual increase in the cut of timber from the national forests, the cut has never been a potent factor, since not more than 5 per cent of the stumpage comes from this source. Approximately 8,000,000 acres of timberland had been cut over by 1948.

Originally, all the cutting in the region was for saw logs. In recent years, especially since 1925, with the development of the pulp and paper industry, several operators are cutting exclusively for pulpwood, whereas others are cutting for both saw logs and pulpwood. In most instances, the development of the pulp and paper industry has not had much effect upon utilization. Much merchantable material is still left in the woods on both saw-log and pulpwood operations.

Ever since logging operations developed on an extensive scale, operators have suffered financially from overproduction. It is estimated that, during the years of largest production, approximately 300,000 acres were cut over annually.

The Effect of Past Practices

The early logging was done chiefly by animal power over relatively small areas. Under the circumstances the fire hazard was not excessive, and disastrous fires did not often occur. In the absence of fire

the scattered trees left on the cut-over land usually restocked the land fairly well.

Power yarding, first used in the Douglas-fir region in 1890, had practically replaced animal power by 1900. High fire hazards were created, and destruction of standing trees became general as extensive operations grew common. The establishment of reproduction was therefore uncertain, and, even where seedlings did start, fire frequently destroyed them. Denuded acreage, therefore, increased rapidly.

Although more precautions are now taken to prevent fire, and protective agencies are more common and more competent than 40 or 50 years ago, fire on cut-over land is still the chief cause of the increasing denuded acreage. Many cut-over lands have been burned over three or four times. Under these conditions the establishment of reproduction is impossible. Fire has been less destructive on national forest than on private lands. Where fires have been kept out, the logged-off land on national forests has regenerated fairly successfully, even though, in many cases, the seed trees have been gradually destroyed by wind.

To reduce the fire hazard on cut-over lands, the slash has been broadcast burned, both on national forest and privately owned lands. This practice has been only partially effective. In some instances a reburn has occurred within a year after the slash disposal. Various weeds then spring up to create a dense cover, which is probably nearly as inflammable as the original slash. Where broadcast burning was applied to land that supported a scattering of young trees, the slash fire killed but did not consume them. Ultimately these trees fall to the ground, increasing the fire hazard.

State laws regulating cutting with the aim of insuring reforestation were enacted in Oregon in 1941 and in Washington in 1945.

A limited amount of planting to restore denuded land to tree production has been done, chiefly in recent years. At the end of 1943, 143,000 acres of successful plantations had been established, of which about one-half were on the national forests (Kummel, Rindt, and Munger 1944). It was estimated that more than 3,000,000 acres would have to be planted to be restored to productivity.

THE FORESTS AND THEIR MANAGEMENT

The forest cover of the Douglas-fir region is diversified, nineteen different forest types occurring here. However, with the exception of a few types, each occupies relatively small areas that, except for the

high-altitude types, are interspersed through the major types. The Pacific Douglas-fir type is by far the most extensive type, while the Douglas-fir–western hemlock, the sitka spruce–western hemlock, the sitka spruce, and the western hemlock are next in importance. Other types represented are: red alder, black cottonwood–willow, Pacific silver fir–hemlock, western redcedar–western hemlock, western redcedar, Port Orford white-cedar–Douglas-fir, redwood, Oregon white oak, oak-madrone, mountain hemlock–alpine fir, Engelmann spruce–alpine fir, red fir, white fir, and lodgepole pine (Committee on Western Forest Types 1945). The less extensive types have been studied very little. The minor conifer types are managed as a part of the major conifer types. Of the hardwood types, the red alder has been given the most attention and will be discussed briefly later.

Virgin forests no longer dominate the region to the extent they once did. In 1945, 48 per cent of the commercial forest land was second growth.

PACIFIC DOUGLAS-FIR TYPE

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of Forest

Importance.
- Area—Major, constituting 50 per cent of the forest-land area.
- Commercial Value—High.

Sites Occupied—A variety of soils, all characterized by rapid drainage and therefore relatively dry. Best development is on the better sandy loams.

Associated Species.
- Major—Douglas-fir 80 per cent or more.
- Minor—Western hemlock, grand fir, western redcedar, Pacific silver fir, noble fir at higher altitudes, sitka spruce along coast, California incense-cedar in southern Oregon.

Place in Succession—A subclimax type that follows forest removal by fire, logging, insects, disease, windfall, or a combination of these. On drier sites, it may be climax. As stands approach maturity, such tolerant species as western hemlock and western redcedar develop in the understory (Munger 1940). Most of the old stands occur as climax types of Douglas-fir–western hemlock, but some occur as western redcedar, western redcedar–western hemlock, Pacific silver fir–hemlock, or Port Orford white-cedar–Douglas-fir types (Committee on Western Forest Types 1945).

Old-growth Douglas-fir stands, although originating as even-aged forests, are uneven-aged, much of the understory of hemlock and other tolerant species having developed after the Douglas-fir reached maturity. This old growth is large, trees 5 to 6 feet in diameter and 250 feet tall being common. They produce large volumes, averaging 30,000 to 60,000 board feet per acre over extensive areas, with individual acres yielding 100,000 board feet. Because of their freedom from limbs to heights of 100 to 150 feet, sound trees yield a high proportion of high-quality lumber (Fig. 60).

Photograph by U. S. Forest Service.

Fig. 60. A typical virgin stand of Douglas-fir. Most of the trees are free of limbs to a considerable height.

Unfortunately, defect runs high in old-growth timber, commonly exceeding 20 per cent and occasionally constituting as much as 55 per cent of the merchantable volume (Boyce 1932). The numerous hemlocks and cedars of pole size and larger in the understory make the old-growth stands dense in spite of the more or less broken upper canopy.

Second-growth stands, usually even-aged, are represented by many age classes, but those under 35 years old are more extensive in area. These have originated on either burned or cut-over land. In general,

they are well stocked, over wide areas approximating 80 per cent of normal stocking (McArdle and Meyer 1930). The trees in second-growth forests are sound, less than 1 per cent of the volume in stands under 100 years old being defective (Boyce 1923). In 1945, 3,317,740 acres were classified as nonrestocked burns and old cut-overs. This implies that this area was virtually unproductive of timber.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction of Douglas-fir is seldom present in old-growth or mature, second-growth forests, but western hemlock, western red-cedar, and various firs may be quite abundant. Since, under any of the types of logging practiced, destruction of reproduction is extensive, provision must be made for the establishment of reproduction after cutting if a fully stocked stand is to be maintained.

Subsequent Reproduction. More recent investigations (Isaac 1935, Isaac and Meagher 1936, Munger 1930) have disproved Hofman's theory (1917) that Douglas-fir seed does not germinate in the uncut forest but remains viable in the forest litter for several years and then germinates when the forest is opened by cutting. It is now evident that Douglas-fir seed that falls to the forest floor and escapes rodents or birds either germinates or decays within 1 year both under virgin timber and on open cut-over land (Isaac 1935). Therefore, it is necessary to make provision for a continuing source of seed if cut-over land is to reproduce completely, except possibly on areas cut during the fall, winter, or early spring following a heavy seed crop.

Douglas-fir produces some seed every year except 1 year out of every 4 or 5, when seed production fails (Isaac 1943). Heavy seed crops, once estimated to occur every 2 or 3 years (Hofman 1924), are borne about once every 4 to 5 years. During a 33-year period from 1909 to 1941 Douglas-fir produced seven abundant seed crops, six medium crops, thirteen light seed crops, and seven failures.

Theoretically, under ideal conditions, 1 pound of Douglas-fir seed (40,000 seeds) per acre should be adequate for satisfactory stocking of reproduction. However, under the conditions that are likely to occur on average cut-over land, 8 pounds of seed per acre over a period of 6 to 8 years—the yield of eight trees—are considered necessary to insure success in regeneration (Isaac 1943). This seemingly excessive number of seed trees is needed partly because at least half of the seed trees are lost during the regeneration period—usually more when they are left singly. As Isaac (1930) has found that Douglas-fir seed from relatively short trees—150 feet tall—was disseminated to a

distance of 1000 feet in sufficient quantity to provide for a well-stocked stand of reproduction under favorable site conditions, small clearcut areas or narrow clearcut strips may be well supplied with seed from adjacent uncut stands. Enough seed for effective regeneration may be disseminated from tall timber to a distance of a quarter of a mile or more.

Contrary to general belief, defective parents are not objectionable in the case of Douglas-fir. They produce as large seed crops as sound trees, their progeny (at least from parents infected with red ring rot) is as vigorous and fast-growing as the progeny of healthy parents at the end of 20 years (Munger and Morris 1936), and the danger of transmission of the disease to the new generation is nil (Boyce 1927) (see p. 372).

Douglas-fir seed is disseminated over a period of several months, between late August and late winter, the cones opening for only a few days at a time at infrequent intervals when the atmospheric humidity is low. In a normal season two-thirds of the seed falls before the end of October. This characteristic of seed dissemination is significant in regeneration, particularly in connection with the slash disposal problem (see p. 369).

The major associates of the type are the equal of, or superior to, Douglas-fir as seed producers. Western hemlock is the most prolific, excellent seed crops being borne nearly every year.

Douglas-fir seed germinates best on mineral soil, but slash is not a serious impediment to the establishment of seedlings, because, by conserving moisture, survival of seedlings may be increased by a cover of slash. Moisture is a paramount factor in seedling survival. Because root development is rapid and thus the roots are able to keep in contact with adequate moisture in gravelly soils, initial survival of seedlings is generally highest on such soils (Fig. 61). Shade—especially dead shade from logs, stumps, and slash—because of its effect on soil moisture and temperature is an important factor in seedling survival. On exposed sites, high soil temperature [2] is the cause of considerable seedling mortality. Locally low temperature in late spring may also be fatal to seedlings. Moderate shrub or tree cover tends to modify

[2] Heat lesions develop on seedlings at a temperature of 123° to 125° F. High mortality of seedlings may occur during extended periods of high temperature. Burned sites are especially adverse to seedling survival, because soil temperature often reaches the lethal point on the blackened surface, and the surface soil has certain physical and chemical characteristics that are unfavorable to seedling survival (Isaac and Hopkins 1937).

the environment sufficiently to reduce greatly some of the causes of mortality. Heavy cover, by reducing light intensity and soil moisture, is detrimental. When overhead canopy exceeds 50 per cent of full canopy, seedling survival is poor and growth of the survivors is very slow. In openings of less than 1 acre, tolerant species increase in number in comparison to Douglas-fir. The ratio of Douglas-fir seedlings

Photograph by U. S. Forest Service.

FIG. 61. A dense stand of reproduction had developed on this Douglas-fir area on a gravel soil. Cutting and broadcast burning occurred 16 years previously.

to western hemlock and balsam firs decreases as the openings in the canopy decrease in size. If Douglas-fir seedlings must establish themselves in competition with dense shrub cover that is several years old, few tree seedlings survive.

Grazing by domestic livestock is not responsible for much seedling mortality except on areas that support a sparse stand of palatable vegetation (Ingram 1931).

Douglas-fir's major associates have higher soil moisture requirements than Douglas-fir; therefore, they generally fail to reproduce on exposed or open sites. They reproduce more successfully on the more

moist sites and where a tree canopy of moderate density occupies the site.

Effect of Competition. Early growth of Douglas-fir seedlings is slow. At the end of one season they are only 1 or 2 inches tall, and not until the sixth year does growth exceed 1 foot per year (Isaac 1943). Growth is affected strongly by the type and amount of competition the seedlings encounter. In one instance seedlings growing in a light stand of weeds were more than twice as tall as seedlings growing in a moderately heavy brush cover. An overhead tree canopy of more than 50 per cent is disastrous to Douglas-fir seedlings. On the other hand, the tolerant western hemlock, sitka spruce, western redcedar, and balsam firs are able to survive under intense competition, and, although their growth may be slow, they are ready to take advantage of small openings that develop in the canopy or ground cover.

If Douglas-fir succeeds in becoming established on sites supporting heavy vegetation, it holds its own with its associates because of its superior growth. The vegetation retards it, but if it can survive the competition it eventually overtops the vegetation.

Windfall. Douglas-fir on dry sites has a well-developed root system, but on moist sites it has a tendency toward shallow rooting (Munger 1927), which makes it very susceptible to windfall there. Even on dry sites trees isolated by cutting are frequently windthrown. As many as 70 per cent of the seed trees, when left singly, have been lost within 10 years after cutting on many cut-over lands. Small groups of trees are less susceptible to windthrow on cut-over land. Because of shallow root systems, the associated species are, on the whole, less resistant to wind than Douglas-fir.

Economic Basis

Utilization and Marketing Problems. Recent developments in logging and transportation methods are of profound significance in the application of silviculture to the Douglas-fir type, as well as the sitka spruce–western hemlock type. Extensive experimentation has demonstrated that logging can be done more economically by a flexible system that makes use of caterpillar tractors, small sledded or tractor-mounted gasoline highlead donkeys, skyline swings, motor trucks, and roads than by the exclusive employment of the power skidder and railroad transportation (Brandstrom 1933, Kirkland and Brandstrom 1936, Rapraeger 1934). A saving of as much as $2.10 per thousand board feet in logging cost has been reported (Brandstrom 1933). Great variation was found in the cost of removing from the woods trees of

different sizes, the extremes being $0.23 per thousand board feet for trees over 40 inches d.b.h. and $0.73 for trees between 18 and 30 inches d.b.h.

The system of roads developed in this flexible system of logging, which features the caterpillar tractor, is significant not only because of its economy—the initial cost and maintenance being less than one-third as much as that of a railroad system—but also because of its subsequent value in making intermediate cuttings for pulpwood, posts, poles, etc., in young stands economically feasible (Kirkland and Brandstrom 1936). Potentially the market for pulpwood is large, since there were, in 1930, twenty-six pulpwood mills in the region. The extent to which this material can be taken from young stands depends, however, on properly coordinated logging.

These studies have shown that the marginal tree for Douglas-fir saw logs varies from 24 to 30 inches d.b.h. (Kirkland and Brandstrom 1936).

Douglas-fir, western redcedar, and sitka spruce, employed chiefly for saw logs and special products, are the most valuable species. Sitka spruce is particularly valuable as pulpwood but is seldom present in sufficient quantity in the Douglas-fir type to segregate it for this purpose. Douglas-fir is popular for Christmas trees, which can be secured from stands 5 to 15 years of age. Other products that can be secured from stands during various stages of their development are: fuelwood, car stakes, and pulpwood, 20 to 25 years; poles, ties, and car decking, 30 to 40 years; piling and saw logs, 45 to 50 years (Douglas-Fir Second-Growth Management Committee 1947). Unless every effort is made to secure well-stocked second-growth stands (Fig. 61), or, if this attempt fails, to resort to artificial pruning, the reputation of Douglas-fir lumber for its high quality—the lumber coming almost entirely from old-growth stands—will not hold, because open-grown second-growth stands yield a very low-grade product, owing to the prevalence of large knots (Paul 1932).

Growth and Rotation. Growth of Douglas-fir stands is rapid, small saw logs being produced on the better sites in 50 to 60 years and on the poorer sites in approximately 80 years. However, unless the size of the marginal tree becomes smaller in the future than it is now, fully stocked second-growth stands will not reach economic maturity in less than 80 years (McArdle and Meyer 1930). Douglas-fir and sitka spruce are the fastest-growing species.

Financial Aspects. That natural regeneration is, with few exceptions, more economical than artificial regeneration is obvious from an

analysis of facts. In 1946, planting cost varied with such local factors as terrain, transport, and brush cover from $12.70 to $20.00 per acre (Douglas-Fir Second-Growth Management Committee 1947). The average cost was $16.00. Although direct seeding has been accomplished for less than half the cost of planting, it has not proved to be a dependable method of artificial forestation. There are indications that successful reproduction can be secured by a system that combines clearcutting of small areas and partial cutting, which will add to the cost of logging only the difference between the expense of careful and careless logging. Under a system of leaving seed trees the cost of reproduction may be little or much, depending on the type and number of trees that must be retained. If defective trees containing little or no merchantable material can be left, the investment in seed trees rarely exceeds $2.00 to $3.00 per acre. When some sound trees must be retained the cost may run as high as $6.00 to $8.50 per acre for reproduction. The net growth on these trees should pay for the interest on the investment.

Application of Methods

Douglas-fir forests are so irregular in age and size-class distribution over an extensive area that a single method of cutting cannot be recommended for all situations. Several different methods show promise, but it is necessary to select the method that best fits each particular case. Clearcutting is adaptable to a variety of stand conditions, both old-growth and second-growth mature stands. Partial cutting in the form of selection cutting, especially if the cut is relatively light, inevitably leads to a change in composition with its attendant lowering of value. Operators who wish to prolong their cut may find some advantage in selection cutting. Shelterwood cutting is less objectionable from the standpoint of its effect on composition, especially if the first cut is heavy and the second cut can be made relatively soon after the first. Seed-tree cutting can be used successfully only on sites where the trees are windfirm.

Clearcutting. Where numerous small areas of high-value timber are intermingled with areas of low commercial value, the setup is ideal for the application of clearcutting of scattered blocks. Ames (1931) advocated this system for national forest timber sales, and Hanzlik (1940) favored some form of clearcutting for all mature and overmature stands containing 80 per cent or more of Douglas-fir. Annual cutting areas must be kept small, never over one-half mile wide if

green timber surrounds the area, or one-fourth mile wide if timber bounds the cut-over area on only one side.

Clearcutting can be employed also in extensive areas of high-value timber. It is necessary in such stands to pay special attention to certain details, such as the retention of the timber adjacent to the

Photograph by U. S. Forest Service.

FIG. 62. A combination of staggered settings, seed blocks and strips, and scattered seed trees provides for adequate regeneration in the Douglas-fir type when fire can be controlled.

cut-over land until it has produced at least one good seed crop; or, if this is not practicable, strips or patches of uncut timber (in reality groups of seed trees) should be left to break the continuity of the clearcut areas (Fig. 62). This alternative method may be accomplished by: (1) leaving marginal long corners between settings (to be selectively cut later if desired), (2) leaving strips of timber along creeks, across valleys, along ridges, or natural fire breaks, (3) leaving immature timber wherever it occurs under conditions that permit its preservation, and (4) such methods of logging as staggered settings and the leaving of the uncut settings for as long a period as practicable

(West Coast Lumbermen's Association and Pacific Northwest Loggers' Association 1937).

Partial Cutting. Shelterwood cutting offers promise of success with mature second-growth stands especially on sites requiring some protection as an aid in the establishment of reproduction. This method should not be attempted unless the stand is sufficiently windfirm to allow heavy cutting and unless a second cutting can be made relatively soon after the first. Although not established by research, there are indications that the cutting should remove 75 per cent of the canopy (Douglas-Fir Second-Growth Management Committee 1947). How long the reserve stand may be left is not known.

Selection cutting has a minor place in the management of stands in which perpetuation of Douglas-fir is the objective. When employed to remove selected classes of material—as it sometimes is—it is not a silvicultural system; rather, it is a system of cutting aimed at taking advantage of existing market conditions in order to furnish greater profits. Where an understory or an admixture of many small trees exists in a stand, selection cutting can be used as a temporary expedient to save the unmerchantable material, which, upon reaching merchantable size, should be harvested by clearcutting.

Douglas-fir cannot be maintained in the new crop unless more than half of the crown canopy is removed. Cutting as heavy as that invites windthrow. Therefore, if a heavy cut under the selection system is made, salvage cutting of windfalls will be necessary if they are not to be a total loss. Selection cutting therefore must be used with caution and a full realization of its implications.

Seed-Tree Cutting. The seed-tree method has little to recommend it, but where only a crude form of silviculture can be followed and the site has low susceptibility to windfall, it can be used (Fig. 63). Single seed trees can be left where the windfall danger is nil and groups of seed trees where there is some danger of windfall. Defective trees may remain as seed trees (Boyce 1927), provided that they have well-developed crowns, are sufficiently healthy to live at least 10 years, and are windfirm. Seed trees can be left to advantage near ridge tops where they will have their maximum effectiveness in seed dissemination, but they should not be kept on the tops of ridges because of the high windfall danger there. Where power skidders are used, proper location of the seed trees—they should never be retained within 150 to 200 feet of log landings and railroad spurs—is of vital importance in preventing their loss during logging (Munger 1927).

Douglas-fir should be the first choice in the selection of seed trees.

but other species, notably western redcedar and sitka spruce, can be left to supplement the seed supply on sites to which these species are well adapted.

Cultural Operations. Thinning and pruning in immature stands, and liberation cutting or some other stand-improvement measure in

Photograph by U. S. Forest Service.

FIG. 63. Eleven years after seed-tree cutting and broadcast burning, this Douglas-fir cut-over land is only partially stocked with reproduction. A fairly dense stand of vegetation has developed.

decadent old-growth stands, are needed silvicultural operations, but research has not gone far enough on these phases of silviculture to furnish many specific details of application.

Although early thinning can be expected to result in increased diameter growth and improved health and sturdiness of the trees (Meyer 1931), it is generally considered best to postpone thinning until it will pay its way (Douglas-Fir Second-Growth Management Committee 1947). However, McCulloch (1943) advocated nonrevenue low thinning in areas of potential ice damage to develop resistance to breakage. Thinning can begin earliest where trees can be marketed

advantageously as Christmas trees. Elsewhere the start of thinning has to be gauged by local markets for small materials. Removal of no more than 30 per cent of the volume of the stand has been advocated.

Pruning is certainly necessary in understocked stands in which the trees have not passed beyond the size that can be benefited (Paul 1932). Pruning of 100 trees per acre in stands between 20 and 40 years of age has been suggested.

Experiments are now in progress to determine practical ways of improving decadent old-growth stands.

Planting. Planting must occupy an important place in the silviculture of the Douglas-fir type. It will be needed on existing poorly stocked lands and as a supplement to natural reproduction for many years even under cutting methods that supposedly are satisfactory for natural reproduction.

Douglas-fir is the most satisfactory species for a wide variety of sites. Other species may be planted in mixture with Douglas-fir on certain sites—western redcedar on wet or acid soils, Port Orford white-cedar in milder, moister parts of the region, and western hemlock on humid, cool sites (Kummel, Rindt, and Munger 1944). A 2-year root-pruned Douglas-fir seedling is the most economical class of stock. Stock grown from seed selected from especially high-quality parents grown at much the same altitude as that of the planting site is particularly recommended (Munger and Morris 1936).

In the Cascades, spring planting is best; in the coast region, planting can take place fall, winter, or spring. Spacing should be 8 by 8 feet. Slit planting, employing the grub hoe, is satisfactory.

Site preparation should include: (1) felling of snags on fire lines, (2) construction of fire breaks, (3) removal of cover, and (4) grazing by sheep and goats if area supports vegetation that is palatable to these animals.

When planting is done on areas supporting large rabbit or rodent populations, the planting stock should be sprayed in the nursery, before lifting, with a strychnine lacquer.

Direct seeding has not proved sufficiently dependable to recommend (Kummel, Rindt, Munger 1944).

Slash Disposal

Slash in Relation to Fire

Slash on clearcut areas makes a large contribution to the fire hazard, because the slash volume is large and the slash becomes inflammable

during dry weather, owing to its complete exposure to the elements. Decline in slash hazard is slow, because only after decay has entered the slash and perennial vegetation shades it sufficiently to prevent excessive drying is there a marked reduction in slash inflammability (Childs 1939). Within 5 years after logging, one-third to one-half of the sapwood of tops and small cull logs becomes decayed, but thereafter decay progresses more slowly. Decay does not progress rapidly enough to facilitate fire control materially during the period when rapid control is most likely to be necessary.

Because of its smaller volume, lower inflammability, and more rapid decomposition, slash in partially cut stands creates less fire hazard than slash in clearcut stands; nevertheless, slash-covered partially cut stands represent a high fire hazard.

Burning of the slash reduces the fire risk; this is the *one* advantage of slash burning. Immediately after broadcast burning, the hazard of an unburned area is eighteen times that of a burned area; gradually the hazards of the two areas approach each other until they are equalized 20 years afterwards (Munger and Matthews 1941). The aggregate danger during the two decades is in a ratio of 1.6 for the unburned area and 1.0 for the burned area.

Ecological Effects of Slash and Slash Burning

Slash, by providing protection, is probably beneficial to the establishment of reproduction on clearcut or heavily cut areas, except where the slash accumulation is very heavy. On lightly cut areas slash probably has a neutral effect.

Burning of the slash, especially when the burning is on an extensive scale in the form of broadcast burning, has several detrimental effects, namely: (1) the slash fire may destroy seed that has fallen to the ground;[3] (2) the slash fire causes certain physical changes in the soil which adversely affect seedling survival; (3) the blackened soil surface resulting from the fire causes high soil temperatures, which, in turn, cause high seedling mortality; and (4) the high concentration of plant nutrients in the surface soil, the result of the burning of the debris, induces the development of seedlings with large tops and shallow roots, a type of seedling that is likely to be very susceptible to summer drought (Isaac and Hopkins 1937). In addition, broadcast burning

[3] If the slash is burned early in the autumn, only a small amount of the seed will be burned because little seed has then been disseminated (see p. 360); but, if it is burned in late winter or early spring, a large part of the seed crop will have fallen and will, therefore, be destroyed by the slash fire.

kills all advance reproduction, some potential seed trees, and often some adjacent timber (Munger and Matthews 1941).

Application of Methods

Since it has been demonstrated that slash burning is primarily advantageous in reducing the fire hazard and generally disadvantageous silviculturally, it is evident that slash burning should be applied only when other measures will not reduce the fire hazard adequately. In general, slash burning should be kept to a minimum.

Broadcast, Spot, and Strip Burning. Various persons who have studied the slash disposal problem carefully are in agreement that broadcast burning is necessary under certain conditions. Broadcast burning is applicable on lands where: (1) the chances of accidental fires are high or opportunities for fire control are poor, (2) clearcutting is employed and an understory is not present, (3) the conflagration hazard is high due to very extensive areas of recent cuttings (Haefner 1927, McArdle and Isaac 1933, Munger and Matthews 1941). Burning is also advantageous wherever debris and ground cover are so dense as to prevent seedling establishment (Isaac 1943). No burning or partial burning in the form of spot or strip burning may be applied where: (1) a reserve stand or understory is left, (2) a cut-over area is well isolated from risk of fire and is not a particularly high hazard in itself, (3) a good stand of advance reproduction exists or subsequent reproduction is likely to materialize quickly, (4) an abundance of seed from the current year's crop is on the ground or a good stocking of seedlings has germinated since cutting. Haefner (1927) describes sections of low to intermediate fire hazard as follows: (1) areas on which the debris of logs and broken timber is light or does not exceed 5000 to 6000 board feet per acre of logs over 6 feet in length and over 6 inches in diameter at the small end; (2) areas on which the brush cover is scattered; (3) areas that are surrounded by green timber, or burned-over areas that serve as fire breaks; (4) areas away from railroads, highways, and other avenues of human travel; (5) areas that can be patrolled during the peak of the fire season if necessary.

When broadcast burning, or any of its modified forms, or spot or strip burning is used, careful attention to the details of application is important. The slash should be burned promptly. This implies that burning should be done both in fall and in spring. When there is a choice of season, however, fall should be chosen, because a fall burn consumes the slash more completely and it avoids the danger of hold-over fires in snags and down logs that is associated with spring burn-

ing (Washington Forest Fire Association). In general, spring burning can be limited to areas cut over the previous winter. Thorough mop-up of spring fires is essential.

Choosing the proper time to burn is of vital importance. Since weather plays such an important role in the success and safety of the slash burning, weather forecasts should be followed closely, with the objective of burning when the slash is dry but high humidity or rain is certain within 24 to 48 hours. By no means should burning be attempted during periods of high wind. Other precautions should include: (1) confining a slash fire to an area with such definite boundaries as railroad grades, streams, green timber, fire trail, or old burn; (2) burning out, first, areas of slash adjacent to valuable property, such as green timber, buildings, bridges, etc.; (3) setting the fire at the right time of day, i.e., late afternoon or evening.

Piling and Burning and Swamper Burning. Slash disposal in partially cut stands is still in the experimental stage; therefore, only a few generalizations can be made. The real difficulty lies in disposing of the slash without damaging the reserve stand or without unreasonable expense. On areas of high hazard either complete or partial piling and burning or swamper burning seems best, whereas on areas of low hazard special protection of the cut-over land, without treatment of slash, should suffice. Careful application of spot or strip burning constitutes a possibility, also.

Special Protective Measures. Because of the high hazard of the slash on most clearcut areas before it is burned, tracts being logged must be given special protection (Ames 1933). This special protection should include: (1) felling all snags over 15 feet high and 12 inches in diameter, (2) cleaning up all debris along railroad rights-of-way before the beginning of the fire season, (3) clearing away inflammable material from donkey settings, and (4) wetting down the ground for a radius of 75 feet around each donkey engine every morning, noon, and evening.

Intensive protection on both burned and unburned areas is necessary until a well-established young stand is developed.

Disease and Insect Problems

The *red ring rot,* caused by the ring scale fungus, is the most damaging of all rots, accounting, on the average, for 80.8 per cent of all defect in Douglas-fir (Boyce 1932). It attacks both Douglas-fir and sitka spruce. Fortunately, this rot is a disease of mature timber,

having destroyed only 1.4 per cent of the merchantable timber at 110 years on site II (Boyce 1932). Even in 150-year-old trees decay is not extensive; but in 300-year-old trees annual increase in decay equals annual wood increment, and in trees over 300 years old increase in decay exceeds wood increment.

Three other rot-producing fungi, namely, the velvet top fungus, the quinine fungus, and the rose-colored Fomes, damage Douglas-fir. The *red-brown butt rot,* caused by the velvet top fungus, is the most detrimental of these because it attacks the butt, thus making severely injured trees subject to windfall. Many other fungi attack Douglas-fir, but none, except the heartwood destroyers, do damage of economic importance.

The *brown stringy rot* is prevalent in the white fir and western hemlock trees 100 years and older. It progresses rapidly in trees over 100 years old, seldom extending beyond the first log; and, in the advanced stage, only the sapwood is sound at the base.

Salvage of merchantable trees, felling or girdling of unsalable trees in old-growth forests, and use of a rotation of less than 100 years for the balsam firs and 150 years for Douglas-fir (which would be the practice in managed forests irrespective of the rot menace) are practical means of controlling the rot-producing fungi.

Tree-killing insects ordinarily are of little consequence. The *Douglas-fir beetle* occasionally attacks after windfall, fire, logging, or other disturbances or when stands are weakened by severe competition or abnormal climatic conditions. Under such circumstances groups of trees are killed by it. Practices that maintain stands in a thrifty condition generally keep damage low. Numerous forest insects have been identified doing minor damage to Douglas-fir forests but rarely is their effect serious (Douglas-Fir Second-Growth Management Committee 1947).

The *hemlock looper* occasionally defoliates and kills Douglas-fir, but its principal activity is confined to the sitka spruce–western hemlock type (p. 378).

Control of Animal and Logging Damage

Temporary regulated grazing of livestock for a 10- to 15-year period after cutting is recommended for areas that support adequate palatable forage—these are clearcut and heavily cut areas—since it aids in reducing the fire hazard (Ingram 1928), and it apparently is not harmful to young seedlings (Ingram 1931). As the vegetation

on cut-over lands consists chiefly of weeds and shrubs, these lands are best suited to sheep. Some areas support enough grass to take care of a light stocking of cattle, but grazing by cattle under such circumstances would be an uneconomical venture. On steep slopes where slash has been burned, sheep should not be allowed to graze for 2 or 3 years (Munger and Matthews 1941). Grazing must be moderate, and, since cut-over lands vary greatly in carrying capacity—from one-fourth to 5 surface acres per head per month for sheep—it is essential to study carefully each area before allocating livestock to it. The grazing season can be from May 1 to October 15.

Some old cut-over lands support large rabbit and rodent populations. When planting is done on such areas, their control, best accomplished by spraying the trees with a strychnine lacquer, is essential.

Where the power skidder is used for logging, particular attention must be given to the control of damage to seed trees. The most practical means of accomplishing this is to leave no seed trees in the most dangerous zone—not closer than 150 to 200 feet to the skidders—and to retain the majority of them at the outer edge of the setting. In stands supporting numerous saplings and poles, control of logging damage should be concentrated in laying out the skid trails where they will do the least harm.

Where tractors are employed for logging, logging damage can be controlled by careful location of tractor roads and some discretion in the use of the tractors. In second-growth timber, bunching of the logs by horses or with a small tractor before yarding is recommended to prevent damage (Kirkland and Brandstrom 1936).

SITKA SPRUCE–WESTERN HEMLOCK TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest

Importance.

Area—Secondary, about 2,000,000 acres.

Commercial Value—High.

Sites Occupied—Chiefly on the humid western slopes of the Oregon Coast Range in a strip 25 to 30 miles wide (Cary 1922), but on cool, moist slopes and in creek bottoms it may extend inland as much as 50 miles (Committee on Western Forest Types 1945).

Associated Species.

Major—Sitka spruce and western hemlock together constitute 80 per cent or more.

Minor—Douglas-fir, western redcedar, and, locally, red alder.

Place in Succession—Essentially a climax type, but the western hemlock type may be the true climax type. The latter, made up of 80 per cent of western hemlock, has the same associated species as the sitka spruce–western hemlock type in the fog-belt area.

Associated with the sitka spruce–western hemlock and the western hemlock types is the subclimax sitka spruce type, which usually appears after denudation. This type consists of 80 per cent sitka spruce. The most common associate of the spruce is western hemlock. Other species found in light mixture are Douglas-fir, Pacific silver fir, western redcedar, Port Orford white-cedar, and red alder.

In such characteristics as form of stand, density, and volume per acre the sitka spruce–western hemlock type is similar to the Douglas-fir type (see p. 357). Sitka spruce generally is less defective than the Douglas-fir and western hemlock. Of the 2,000,000 acres of this type about 1,000,000 acres are old-growth timber, and the other 1,000,000 are second growth, about equally divided between small second growth and advanced second growth (Meyer 1937).

Stand Regeneration and Development. *Advance Reproduction.* Western hemlock, western redcedar, and Pacific silver fir are the major constituents of the advance reproduction, sitka spruce being very sparingly represented. Advance reproduction is sometimes abundant in mature stands.

Subsequent Reproduction. Sitka spruce does not reproduce as readily after cutting as its chief associate, western hemlock, owing undoubtedly to its sparing seed production and its apparent difficulty of becoming established on sites with a thick litter (Meyer 1937). Sitka spruce seed germinates in practically any type of seed bed if moisture is abundant (Brandstrom 1933, Western Forestry and Conservation Association 1929). Seedling survival is best in mineral soil, apparently because of the more stable moisture conditions there than in litter. Evidence of the moisture factor in seedling survival is the high survival of spruce seedlings on north slopes and under the shade of branches. Whether stand density is a significant factor in seedling survival other than through its effect on soil moisture is not known. A heavy cover of vegetation such as may develop on areas heavily cut a few years before is a serious obstacle to the establishment of spruce seedlings; on the other hand, a 75 per cent cover of bracken fern does not adversely affect seedling survival.

Western hemlock is a constant and prolific seed producer. Its seed germinates well on almost any kind of seed bed. Survival of seedlings is high, even in a dense forest, when moisture is abundant. Exposed south slopes are unfavorable to both seed germination and seedling survival.

Pacific silver fir and western redcedar reproduce best in an environment that favors the regeneration of western hemlock.

Photograph by U. S. Forest Service.

FIG. 64. Seed trees are often windthrown soon after cutting in the western hemlock–sitka spruce type.

Effect of Competition. Differences in growth and tolerance of the species that comprise the sitka spruce–western hemlock type are of minor significance in the struggle for existence, because all species do not grow well on the same site. In other words, site adaptability probably determines ultimate survival and growth. In general, however, the rapid juvenile growth of the sitka spruce gives it an early advantage on many sites. Western hemlock has few equals for persistence; therefore, once established, it will always be represented in the stand. All species are sufficiently tolerant to survive in dense stands, but growth is, of course, retarded under such circumstances.

Windfall. Both western hemlock and sitka spruce are very susceptible to windthrow. Windfall is generally spotty in uncut forests except when the wind attains hurricane velocity, as was the case on the Olympic peninsula in 1921 when, over large areas, the forest was completely destroyed (Boyce 1929). Isolated seed trees on cut-over land seldom withstand the wind for more than a few years (Fig. 64).

Economic Basis

Much that was related about the economics of the silviculture of the Douglas-fir type applies to the sitka spruce–western hemlock type. Many of the cases used in the study of the economics of cutting were taken from the sitka spruce–western hemlock type.

Both sitka spruce and western hemlock are valuable for pulpwood, the former particularly so. All species have value for lumber, but the market for the balsam firs is very weak. Western redcedar is most valuable for shingles and poles.

Saw logs can be grown on a rotation of 70 years. The stands yield some pulpwood at 30 years.

Application of Methods

The reproduction cutting methods recommended for the Douglas-fir type give reasonably good results when applied to the sitka spruce–western hemlock type. The windfall hazard makes seed-tree cutting the least desirable method. Clearcutting has the drawback of providing no protection to the site, but, by keeping clearcut areas very small, proteection from adjacent stands of timber may be sufficient to aid the establishment of spruce and hemlock seedlings. Single-tree selection that gives maximum site protection is an effective cutting method for this type (Fig. 65). If 15 to 50 per cent of the stand volume is removed, a cutting cycle of 6 to 15 years seems feasible. Sitka spruce should be favored wherever it is well adapted to the site.

Although little is known about the technic of thinning young stands, it is apparent, owing to the tendency of sitka spruce to develop water sprouts or epicormic branches when overexposed, that thinning must be light (Meyer 1937).

Planting can follow the general plan outlined for the Douglas-fir type (p. 368) except with respect to species choice. Sitka spruce should be the favored species. Western redcedar, Port Orford white-cedar, and western hemlock can be used effectively in mixture. Direct seeding seems to be feasible on sitka spruce–western hemlock sites, although it has not been so demonstrated conclusively by extensive

trial. When sowed on the best sites, free of brush cover within 2 years after cutting, broadcast sowing of 1 to 2 pounds of seed of small-seeded species can be expected to yield reasonably satisfactory results.

Photograph by U. S. Forest Service.

Fig. 65. The residual stand left after partial cutting in the western hemlock-sitka spruce type. Tractor logging makes partial cutting possible.

Slash Disposal

Slash from cutting is not so hazardous in the sitka spruce–western hemlock type as in the Douglas-fir type, because the sites it occupies have less acute fire weather, the flashy fuels disintegrate more rapidly, and the sites develop a cover of fire-retardant vegetation more quickly than sites occupied by the latter type (Munger and Matthews 1941). For these reasons partial disposal and no disposal are appropriate for most of the cut-over land. The technic that is used in the Douglas-fir type should be employed here (see p. 370).

Disease and Insect Problems

The same rots that attack the Douglas-fir type are prevalent in the same species in the sitka spruce–western hemlock type. However, the

percentage of defect is lower in the latter type, especially when sitka spruce, which is relatively free of rot, dominates the stand. Control should take the same form as in the Douglas-fir type (see p. 372).

The *hemlock looper* is a defoliator that periodically becomes epidemic and kills large areas of mature forest, particularly stands containing a high percentage of hemlock. At the height of such epidemics all species of trees, and even shrubs and herbs, may be defoliated and killed. The most recent outbreaks occurred from 1918 to 1921 and from 1929 to 1932. Young forests under 50 to 60 years of age are rarely attacked. After this age, especially when immature stands are intermingled in older stands, they become progressively more susceptible to attack. It is believed that relatively short rotations of managed forests minimize damage by the hemlock looper. If extensive areas are threatened by this insect, direct control by application of 1 pound of DDT mixed in 1 to 3 gallons of water per acre is recommended.

The *sitka spruce weevil* has been severely injurious to young sitka spruce from 5 to 25 feet high, especially in plantations. The damage is identical to that done by the white pine weevil of the East. Weeviling in plantations has been so serious as to raise doubt of the wisdom of planting sitka spruce. Close spacing seems to minimize weeviling.

The *spruce aphid* in recent years has killed millions of board feet of sitka spruce, particularly along the tidelands. Control has not been attempted.

RED ALDER TYPE

The red alder type, although it is one of the minor types of the region, is treated briefly here because it is intermingled with the Douglas-fir and sitka spruce–western hemlock types and should be managed in conjunction with them. It is a temporary type that occurs on burned lands, of either the Douglas-fir or sitka spruce–western hemlock type, that are slow to regenerate, ultimately to be succeeded by one of the two major types. Some of the stands are pure red alder; others contain the common conifers of the Douglas-fir and sitka spruce–western hemlock types as well as Oregon ash, California myrtle, bigleaf maple, northern black cottonwood, cascara, and Pacific dogwood. The conifers often form an understory. The stands are even-aged, moderately dense in youth, but rather open at maturity. The oldest stands, which are about 80 years old, have an average volume of about 25,000 board feet per acre (Johnson, Hanzlik, and Gibbons 1926). The red alder type is the most important hardwood type of the region.

Red alder is a good seed producer and disseminates its seed widely. The seed germinates well in mineral soil or litter. Red alder reproduces also by root suckers and stump sprouts, but these forms of reproduction are less dependable than seedlings (Johnson, Hanzlik, and Gibbons 1926). Red alder seedlings are intolerant; therefore, their survival and growth are best in the open or under a light cover. Whenever conifers are abundant in the advance reproduction or seed in abundantly after cutting, red alder has difficulty maintaining itself in the stand.

Regeneration of the red alder type can be accomplished best by clearcutting small areas. Cleanings will have to follow when conifer reproduction is abundant, if the objective of management is to maintain the type, which is a logical aim because of the scarcity of hardwoods in the region. If advance conifer reproduction is abundant and large, maintenance of the type may be very difficult unless much money is spent for cultural operations. In such cases it is probably best to convert the stand to conifers.

The infection of much of the red alder with white trunk rot at about 50 years makes cutting soon thereafter advisable.

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11 • *Northern Rocky Mountain Region*

DESCRIPTION AND HISTORY

Location and Landownership

The northern Rocky Mountain region [1] occupies all of Idaho north of the Salmon River, a small section of northeastern Washington, and the portion of Montana west of the Continental Divide (Fig. 1). The total land area is approximately 32,000,000 acres, of which nearly 25,000,000 acres (78 per cent) are in forest. The region has two natural boundaries, the Salmon River on the south and the Continental Divide on the east. Approximately 70 per cent of the forested area is owned by federal and state governments. Distribution by ownership and geographic locality is shown in Table 26.

Physiographic Features

The region lies in the northern half of the northern Rocky Mountain province (Fenneman 1930). The most important mountain range is the Bitterroot, which lies in the southwestern part of the region. Other important ranges include the Lewis in northern Montana, the Galton, Purcell, Cabinet, and Selkirk Ranges in northern Idaho, the Coeur d'Alene and Clearwater Mountains in western Idaho, the Flathead and Cabinet Ranges in western Montana, and the Garnet Range in southwestern Montana. Each of these ranges has rather distinctive features, but all have the common characteristic of ruggedness. The slopes are steep and often precipitous. The canyons are deep and narrow; the ridges are sharp, narrow, and angular. This type of topography is broken here and there by gentle slopes, rounded ridges, and occasional plateau-like areas bisected by broad valleys 5 to 15 miles wide.

[1] The region as defined here is an ecological unit and does not coincide with the widely known northern Rocky Mountain region or Region One of the Forest Service, or other administrative or geographic regions less commonly recognized.

The highest elevations are in the Gallatin and Madison Ranges, where there are numerous peaks about 10,000 feet. Most of the region lies below 8000 feet, and the best timber lies between 2000 and 5000 feet. The general trend of the mountain ranges is along a north-south axis, and the drainage is north and west. The streams are pinched in by narrow gorges, many of them 3000 to 5000 feet deep.

TABLE 26

FOREST-LAND OWNERSHIP BY GEOGRAPHIC LOCALITY

Ownership	Geographic Locality			
	Northern Washington *	Northern Idaho *	Western Montana†	Total
	Million Acres			
National Forest	319	6,302	7,192	13,813
State and County	432	804	388	1,624
Other Federal	269	337	1,244	1,850
Private	1,624	2,887	2,917	7,428
Total	2,644	10,330	11,741	24,715

* From Forest Survey Statistics.
† From Extensive Revision, 1931.

In general, the soils are loamy, usually very shallow on the slopes and ridges, and of moderate depth in the canyon bottoms (Bowman 1911). In the Bitterroot Mountains, the soils on the mountain slopes are frequently underlain by granite debris, whereas in the subalpine meadows, the soil is often a pure granite-gravel.

Drainage is complicated in this region of numerous mountain ranges. Many of the streams take a long, roundabout way to reach their destination, frequently almost doubling back on themselves in a short distance. Water courses are abundant, practically every small draw containing a stream. All the drainage eventually reaches the Pacific Ocean by way of the Columbia River.

The Flathead River, flowing south out of Canada into western Montana, and the Bitterroot River, flowing north from the Continental Divide into southwestern Montana, join the Clark Fork, which flows

in a northwesterly direction into Lake Pend Oreille. From Lake Pend Oreille, the Pend Oreille River flows west and then north into northeastern Washington and finally into Canada, where it and the Kootenai empty into the Columbia River. The Kootenai River flows south from Canada into the northwestern corner of Montana, thence to make a horseshoe flowing northwest across northern Idaho into Canada, where it joins the Columbia drainage.

The several forks of the Clearwater drain the southwestern part of the region, flowing in a westerly direction into the Snake River at Lewiston, Idaho. North of this is the Spokane River, fed by numerous small streams, flowing west into the Columbia.

Climatic Features

The climate varies considerably in different parts of the region chiefly because of the wide range in altitude and location with reference to the path of the west-to-east storms. Average annual precipitation for the major part of the timbered area is at least 20 inches and between 25 and 49 inches in many sections (Haig, Davis, and Weidman 1941, Weather Bureau 1926). Uneven distribution is the critical feature of the precipitation. So small a portion of it occurs during the growing season that moisture conditions become critical for plant and tree growth, and the consequent dryness of the ground surface adds greatly to the fire hazard. July and August, the two driest months, have a normal average monthly rainfall of slightly more than 1 inch. Precipitation gradually increases during the fall months, reaching its maximum in November, but being heavy for 3 months thereafter. Approximately two-thirds of the precipitation comes as snow, most of it falling between November and April. Snow attains a depth of several feet and totals more than 15 feet annually in some sections.

The relative humidity is low from June through August. During this period the minimum relative humidity frequently is between 25 and 40 per cent and occasionally 10 per cent. At other times the relative humidity is normally 50 to 60 per cent.

Wide diurnal temperature ranges are characteristic of the summer. Day temperatures of 90° to 100° F. may be followed by a night temperature of 50° F. Freezing temperature may occur during any month of the year. The mean annual temperature for most of the region is between 40° and 50° F. The mean temperature for July, the warmest month, is between 60° and 65° F., and for January, the coldest month, 18° to 25° F. (Weather Bureau 1926). The temperature frequently

falls below zero in winter and may go above 100° F. in summer. Hot spells in summer are infrequent and of short duration. The winter, although cold, is broken occasionally by local chinook winds. The period between killing frosts varies from less than 2 months in the high mountains to more than 5 months at the low altitudes. Most of the region has a growing season of 3½ to 4½ months.

Electrical storms without precipitation, chiefly during July and August, are characteristic of the region and are probably more critical here than in any other region in the United States.

Winds, although variable, are chiefly from the west and southwest (Weather Bureau 1926). The average velocity is not great, seldom above 10 miles per hour. Occasional high winds, with maximum velocities of 30 to 40 miles per hour, have occurred.

Development of Lumbering

Extensive lumbering in the northern Rocky Mountain region is of rather recent date. Before 1900 and for several years thereafter, the industry was only locally important. Before 1911, ponderosa pine was cut much more extensively than any other species, and even as late as 1927 the cut of this species exceeded that of western white pine, owing chiefly to the widespread cutting of the former in Montana and Washington. In northern Idaho the production of western white pine lumber exceeded that of ponderosa pine for the first time in 1911, and thereafter it has held its supremacy. Idaho was ranked among the first twenty-five states in lumber production for the first time in 1908, Montana in 1916. Although some second-growth stands will reach merchantable size, and although some cut-over lands will be ready for a second cut by the time existing merchantable stands are cut over, the available timber volume from these sources will not be able to sustain the present rate of cutting. Cutting of national forest timber has not developed as rapidly as on private lands. Most of the lumber must be sold outside the region, although the state of Montana, which consumed 45 per cent of its lumber production from 1922 to 1936 in contrast to Idaho's 14 per cent, has a fairly good home market.

The Effect of Past Practices

Practices on private forest lands before 1925 were destructive to the forest. Cutting of high-value species was very close, and, in the absence of any conscious efforts at fire protection, nearly all cut-over

land ultimately burned over. Although some of the older cut-over lands are so badly denuded that they can be reclaimed only by artificial reforestation, many have reproduced astonishingly well. Compulsory disposal of slash in Idaho, as required under the forestry law of 1925, has brought about greatly improved slash disposal. Fire protection has been improved through the various timber protective associations. One company that has been practicing forestry since 1928 cuts no trees under 14 inches d.b.h. and has classified its forests into three age groups for the purpose of dealing with its cutting problems (Billings, Rettig, Baggs, and Rapraeger 1942). These practices are leaving cut-over lands in better condition.

The high value of the western white pine for lumber and of the western redcedar of a size that is suitable for poles, and the negligible value of other species in the western white pine type, have been responsible for cutting pine and cedar to low diameters and for the general failure to cut the others. White pine generally fails to reproduce in such stands, even when seed is present, because the canopy is too dense. On the few occasions that a portion of the low-value species has been cut, the pine has reproduced. Unfortunately, fire passing through these stands, occasionally two or more times, has severely damaged cut-over land.

The Forest Service has managed the western white pine type with the objective of increasing the proportion of white pine in future crops. The early cuttings often were not conducive to leaving the stand in the best silvicultural condition, but some of them were very successful. Before 1913, the following methods of cutting were used, chronologically: scattered seed-tree method (one to five trees per acre); clearcutting with blocks of seed trees, 2 to 20 acres in area; seed-tree method, more nearly a shelterwood method because of the numerous seed trees; clearcutting in strips (Haig 1930). Scattered seed trees often suffered heavy loss from windfall before reproduction became established. Too much valuable stumpage was left standing where blocks of seed trees or a large number of scattered seed trees were retained (McHarg, Kittredge, and Preston 1917). Clearcutting was abandoned chiefly because of difficulties in fire control; in some cases the large proportion of low-value species made the method impractical. For a period after 1913 a modified seed-tree method of cutting, more nearly a shelterwood cutting in which all species are considered, was applied. Recently efforts have been made to adapt the cutting method to individual stand conditions with the objective of improving regeneration and controlling *Ribes* and the mountain pine beetle.

Slash was first disposed of by broadcast burning on the theory that exposure of the mineral soil, accomplished in this manner, was necessary for the establishment of white pine seedlings. This type of disposal was not always effective in reducing the fire hazard, under the system of burning then used, and was soon abandoned for piling and burning, a method that greatly lessened the fire hazard and conserved the seed that might be stored in the litter.

Since 1913, defective hemlock and white fir on national forest timber sales have been girdled or felled and burned, thereby reducing their regeneration. On the older cut-over areas, where cutting did remove small trees and where fire did not get into the slash, reproduction is very abundant.

The recent practice on the national forests of complete piling and burning of slash and selective cutting has been effective in maintaining the productive capacity of the larch–Douglas-fir type. Where cutting has been particularly light, partial application of the piling and burning method to the slash has been adequate.

The ponderosa pine type, the first type to be cut extensively and still one of the most important in lumber production, has been treated much the same as this type in other parts of the Northwest (see p. 504). The other types of the region, the lodgepole pine (of little present economic importance and seldom cut) and the Engelmann spruce-alpine fir type, have been exploited to a lesser degree in this region than the other types and, because of this and their lower inflammability, have not suffered extensive denudation.

Through 1947, 113,000 acres of denuded land have been planted by the Forest Service.

THE FORESTS AND THEIR MANAGEMENT

The region is dominated by the western white pine, larch–Douglas-fir, and ponderosa pine types. Only the first two types are discussed here in detail. Occupying smaller areas and breaking the continuity of these types are the Engelmann spruce-alpine fir, and lodgepole pine types (similar to these types of the lodgepole pine region, p. 419). The two types discussed here occur most extensively in separate parts of the region, the western white pine type in northern Idaho and the larch–Douglas-fir type in northwestern Montana. The former occupies an area of approximately 4,000,000 acres, of which approximately one-fourth is poorly stocked burns. Because of its similarity to the same

type of the northwest ponderosa pine region, the ponderosa pine type is not treated in detail here. (The reader may see p. 504.)

WESTERN WHITE PINE TYPE

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of Forest

Importance.
  Area—Major.
  Commercial Value—High.
Site Occupied—Sites between 2500 and 5500 feet, especially north and northeast slopes where moisture and fertility are at moderate to high levels (Larsen 1929, 1940).
Associated Species—Varies with site, locality, and age of stand. Any forest association containing 20 per cent or more western white pine is regarded as a western white pine type (Committee on Western Forest Types 1945).
  Major—Western white pine, most abundant in second-growth stands (average 50 per cent) (Fig. 66); least abundant in overmature stands; western larch and Douglas-fir throughout the region; western hemlock, except in Clearwater district; western redcedar, grand fir (Haig 1933).
  Minor—Lodgepole pine, ponderosa pine, Engelmann spruce, alpine fir.
Place in Succession—Largely temporary, passing naturally to the climax type of western redcedar–hemlock. In the eastern part of the region where the climate is drier, it tends to be replaced by the larch–Douglas-fir type. Heavy cutting of white pine and western redcedar causes a change to either the western redcedar–hemlock or larch–Douglas-fir type.

The mature and overmature forests usually contain two or three age groups and thus are irregular, even though most of them originated as even-aged stands such as characterize the second-growth forests (Figs. 66 and 67). The hemlock in the old-growth forests occurs as a dense understory, usually somewhat younger than the overstory, scattered through the overwood, or in both understory and overstory (Haig 1933). Hemlock, grand fir, and western redcedar of old age are highly defective.

Old-growth stands produce average volumes of 15,000 to 30,000 board feet per acre over extensive areas, individual acres yielding 50,000 board feet. Vegetation is sparse in the dense old-growth and second-growth forests.

Severely burned lands, constituting about 1,000,000 acres, support little tree growth but a considerable quantity of shrubs and herbaceous plants. Unburned cut-over lands represent wide variation in stocking and composition: national forest lands are reasonably well stocked with sound trees—partly high-value species, partly low-value species—and privately owned lands vary from denuded land to lightly and moderately well-stocked stands of defective and/or sound low-value species.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction in old-growth stands is generally sparse. Exceptions to this are openings in stands created by fire, wind, insects, or natural breaking down of the older stands (Fig. 67).

Subsequent Reproduction. Although one of the first studies of western white pine regeneration indicated that there was a possibility that considerable white pine seed might remain viable in the litter for more than 2 years after it was produced (Larsen 1925), more recent study shows that about 25 per cent of it has failed to germinate and is still viable the second year after storage, but that only 1 per cent is viable after 3 years of storage (Haig, Davis, and Weidman 1941; Weidman 1933). Even when adequate seed is produced, conditions for germination and early establishment may be unfavorable for 1 or more years; therefore, some form of continuing seed source must be available if natural white pine reproduction after cutting is to be adequate.

Western white pine is neither a frequent nor a prolific seed producer. Good crops occur on the average at 3- to 4-year intervals, borne chiefly by vigorous dominant or codominant trees over 70 years old with normal crowns (Haig, Davis, and Weidman 1941). A good crop for a single tree is about forty cones containing about 2000 germinable seeds. Rodents, particularly the Douglas or pine squirrel, sometimes destroy a large part of the seed crop.[2] About 90 per cent of the white pine seed falls within 400 feet of the parent tree, much of it before November 1. Western white pine-seed germinates best on mineral or burned mineral surfaces (Larsen 1924). A duff surface is a particularly poor germinating medium on exposed sites because it dries out rapidly, permitting high surface temperatures to develop.

Establishment of white pine seedlings is intimately related to the condition of the site. Seedlings more than 2 years old are fairly well established but their normal development is not insured, because conditions that favor initial establishment do not always promote vigorous

[2] In one case on record 90 per cent of the cones were cut from the trees by squirrels between early August and early October

development. The first season is the most critical, about 50 per cent of all seedlings dying during the first year. On exposed areas—river flats, south and west slopes—high soil temperature is the cause of most of the seedling mortality, after the early losses from damping-off and other biotic agents subside. Shade is essential to good survival on these sites (Haig 1936). On protected locations such as north slopes

Photograph by U. S. Forest Service.

Fig. 66. Dense stands with a high proportion of western white pine sometimes occur after fire. A little Douglas-fir, grand fir, and lodgepole pine is in association here.

heavy cover of trees causes high seedling mortality from drought, because the seedling's root penetration does not keep up with the drying of the surface soil. A moderately heavy brush cover may create drought conditions also. On such sites, light shade or no shade at all favors high seedling survival, because high soil temperature is not an important cause of seedling mortality.

Of the principal white pine associates, western hemlock and western redcedar are outstandingly abundant seed producers. Western larch, Douglas-fir, and grand fir disseminate their seed at about the same time and rate as western white pine. Hemlock and cedar seed dissemination extends over a longer period, 40 to 50 per cent of the seed

Photograph by U. S. Forest Service.

FIG. 67. A typical virgin stand of the western white pine type. Advance reproduction of western hemlock, grand fir, and western redcedar is often abundant in openings.

falling in late fall and winter (Haig, Davis, and Weidman 1941). The seed of these species is seldom viable longer than the normal over-winter period.

Germination of the seed of the white pine associates is best on mineral or burned mineral surfaces. On sheltered sites Douglas-fir and grand fir seeds germinate as well on duff as on any other surface, but not so for western hemlock, western larch, and western redcedar. On exposed sites the initial establishment of western larch, Douglas-fir, and grand fir seedlings is influenced by the same conditions as white pine seedling establishment; in other words, conditions that favor the latter favor the former. On the other hand, western hemlock and western redcedar seedlings suffer heavy mortality from drought on both exposed and protected sites, because their root penetration is too slow to keep ahead of the drying of the surface soil. Therefore, shade is essential to successful seedling establishment on severe sites, but not on sheltered sites.

Stand Development. Once seedlings are established, the ultimate number and position of each species in the stand depend on the ability of each to grow and survive under existing site conditions in competition with their associates. On exposed sites, the intolerant lodgepole pine and western larch seedlings develop best under full-sun conditions, where they make the most rapid initial growth of any species (Haig, Davis, and Weidman 1941). Both overtop white pine there in early life, but eventually the white pine nearly equals larch in height and outgrows lodgepole pine.

White pine grows well with larch and, unless badly crowded, grows up through the latter and forms a large proportion of the final stand. Lodgepole pines tend to develop into "wolf trees," thus holding back and, to some extent, killing white pines of the same age. Douglas-fir and grand fir seedlings on any site grow at about the same rate as white pine (grand fir often exceeds it). The white pine forms an important component of the dominant stand under natural development. The Douglas-fir, because of its vigorous, rather bushy growth, is a serious competitor of white pine when it occurs, which on good white pine sites, is not often. In general, on exposed areas, western white pine, Douglas-fir, and grand fir are benefited by a moderate amount of overhead shade. Western hemlock, on sites with no overhead shade, is normally outgrown by white pine, which, at maturity, forms the bulk of the dominant stand, with hemlock mostly as an understory. On the other hand, western hemlock, under shade and on most north slopes, outgrows slightly the white pine, or, if shade is

heavy, it easily outgrows the pine. Under natural development the hemlock forms an important part of the dominant stand, definitely crowding out the pine. Western redcedar is less aggressive than hemlock and never assumes a dominant position in young stands.

It is obvious that only partial control over the quantity and composition of the young stand is possible through regulation of the residual stand. Effective control depends on proper treatment of the young stand itself. Ten years after heavy cleaning in an 8-year-old stand, which removed all species except western white pine and western redcedar, white pine had the greatest height and constituted 40 per cent of the stand. In a similar untreated stand, white pine seedlings were approximately 35 and 30 per cent as tall as western larch and lodgepole pine, respectively, and they constituted only 1 per cent of the stand. In a stand to which a moderate cleaning had been applied 10 years before, white pine seedlings were approximately 75 and 70 per cent as tall as western larch and lodgepole pine, respectively, and they constituted 22 per cent of the stand.

It should be noted also that understory hemlock and white fir when released make accelerated growth thereafter, growth of both being nearly doubled in the 10-year period after release (Haig 1933). Hemlock trees tend to develop wolf-like crowns after release. Suppressed western white pine trees recover growth slowly when released (Davis 1936).

Windfall. Trees on cut-over lands suffer severe damage during violent wind storms, but a study of twenty-two cut-over areas revealed a loss from windfall of only 3 to 4 per cent of the white pine seed trees. Such storms as occurred in 1924, 1931, and 1933 caused much windfall over extensive areas, the 1931 and 1933 storms uprooting 91 and 75 per cent, respectively, of the white pine seed trees on the affected areas. Western white pine, western larch, and Douglas-fir are the most windfirm species, and white fir and western hemlock are moderately susceptible to windthrow.

Windbreakage commonly occurs in defective hemlock, fir, and cedar.

Economic Basis

Utilization and Marketing Problems. High logging costs and limited local markets [3] are responsible for the low value or even lack of value

[3] Twenty-six per cent of the forest products cut in northern Idaho and 53 per cent of those cut in western Montana are sold in Idaho, Montana, Oregon, and Washington. Fifty per cent of all lumber cut in Idaho is sold east of the Mississippi River.

of low-quality timber and unpopular species. Furthermore, forest industries are not diversified, sawmills using 79 and 76 per cent of the timber cut in Idaho and Montana, respectively. There is some demand for cordwood, mine timbers, posts, piling, railroad ties, and pulpwood. Sound cedar poles are in strong demand, and shingle mills use small quantities of western redcedar.

Relative Value of Species. Of the six or more species commonly associated in the western white pine type, only western white pine and western redcedar used for poles are of sufficient value to log extensively under existing market conditions (Davis 1936). Regardless of future developments, white pine will undoubtedly remain the most valuable species for the region as a whole, although locally, even now, western redcedar when utilized for telephone, telegraph, and power poles has as much or greater value. Cutting of Engelmann spruce, western larch, Douglas-fir, grand fir, and western hemlock means reduced profit from the western white pine because these species seldom have a market value sufficient to carry the cost of logging (Hall 1928, Kock 1923, Neff 1928). The high percentage of defect in hemlock and fir complicates their utilization also. Hemlock has promise for future utilization as pulp.

Based on existing and anticipated markets, the relative value of the principal associated species is shown in Table 27.

TABLE 27

Relative Value of Associated Species in the Western White Pine Type

High Value	Moderate Value	Low or No Value
Western white pine	Engelmann spruce	Alpine fir
Western redcedar	Western larch	Lodgepole pine
Ponderosa pine	Douglas-fir	Western hemlock
	Grand fir	

Marginal Tree. The size of the marginal tree varies greatly for individual species. Western white pine under 14 inches d.b.h. and ponderosa pine and Douglas-fir under 20 inches d.b.h. probably cannot be handled at a profit. Cedar poles under 30 feet in length show little margin for profit. Small amounts of material from trees smaller than these can sometimes be sold as special products for, or slightly in excess of, the cost of logging.

Growth and Rotation. Western white pine grows rapidly, but even in a fully stocked stand on an average site sufficient volume to make logging feasible does not materialize until about 70 years have passed, when the volume in trees 12.6 inches d.b.h. and larger is 12,300 board feet (Haig 1932). Stands at that age are still growing rapidly—the board-foot volume doubles between the sixtieth and eightieth years—and quality is just developing, and so a rotation of at least 120 years is indicated. For the less favorably situated stands a 140-year rotation is preferable. Davis (1942) estimates that volume can be increased 50 per cent and value 40 per cent by means of four partial cuttings in young, thrifty, well-stocked stands, beginning at 90 years, and a 20-year cutting cycle. Existing understocked second-growth stands on the better sites produce 200 to 300 board feet, International rule, per acre annually at 90 to 120 years instead of the 600 to 800 board feet possible in fully stocked stands (Haig 1932).

Western white pine generally has, on the average, about the same diameter increment on cut-over lands as its associates, growth varying on different sites from 0.7 to 1.5 inches per decade. The average increment per decade of other species is as follows: western larch, 0.5 inch; Douglas-fir, 0.8 inch; grand fir, 1.1 inches; western hemlock, 0.7 inch; western redcedar, 0.9 inch (Division of Timber Management 1932). On the Coeur d'Alene National Forest trees with normal crowns grew twice as fast as trees with small, poorly developed crowns. In a stand of western white pine from 20 to 30 years old, pruning of the live crowns of trees with live-crown ratios of 86 to 99 per cent caused no appreciable reduction in the trees' diameter or height growth until 40 per cent or more of the live crown was removed (Helmers 1946).

In deciding upon silvicultural practice in stands containing a considerable volume of sound fir and hemlock in the understory, a knowledge of their growth after cutting and of their anticipated value, particularly as compared to western white pine, is of vital importance. Growth data only are presented here; a financial analysis is given in subsequent paragraphs.

In a study of limited scope Haig (1933) estimated that, at 20, 30, and 40 years after cutting an old-growth white pine forest containing a fairly dense fir and hemlock understory, the yield of the understory in trees 7 inches d.b.h. and larger would be 7350, 11,600, and 17,900 board feet per acre, International rule, respectively. Replacement of the fir and hemlock understory, at the time of cutting, by a white pine stand would be followed by yields of 0, 600, and 4450 board feet at corresponding periods after cutting.

Financial Aspects. The cost of growing western white pine is high,[4] and the value of the mature crop is high. Just what return may be expected on the investment in growing white pine is not clear. Nice judgment is necessary, however, in deciding where to draw the line in expenditures for favoring western white pine over other species; there are situations where it may be better economy to produce chiefly western hemlock and grand fir than pine in the second crop. The uncertainty of stumpage values 40 to 50 years from now makes a sound analysis of the situation hazardous. The present character and condition of the old-growth stand have an important bearing on the problem, also.

Pine vs. Hemlock and Fir. When the hemlock and fir understory is reasonably sound, it may yield a more profitable crop 40 years later than would a white pine crop that could be made to replace it by expensive silviculture. Over a longer period the white pine has greater value, but the immediate problem is concerned with the understory, which can be utilized in 40 years. Tables 28 and 29, taken from Haig's (1933) limited study, show the anticipated returns from the two different crops.

TABLE 28

Stumpage Values of Understory Stands 40 Years after Release

Percentage of Defect	Values per Acre				
	Stumpage Price per Thousand				
	$0.50	$1.00	$1.50	$2.00	$2.50
0	$8.95	$17.90	$26.85	$35.80	$44.75
20	7.16	14.32	21.48	28.64	35.80
40	5.37	10.74	16.11	21.48	26.85
60	3.58	7.16	10.74	14.32	17.90
80	1.79	3.58	5.37	7.16	8.95

The conclusion to be drawn from the foregoing tables is that a sound understory will have a value equal to or greater than a seedling white

[4] Fire-protection costs, not included in this discussion, are also high for this type, probably the highest of those of any forest type in the United States. Even with a good protection system some sections suffer severe losses from fire.

TABLE 29

STUMPAGE VALUES OF WHITE PINE SEEDLING STANDS, 40 YEARS OLD (GROSS VALUES MINUS COST OF $10 AT 3½ PER CENT) *

Percentage of White Pine in Stand	Net Values per Acre				
	Stumpage Price per Thousand				
	$ 0.50 W.H.† 15.50 W.P.‡	$ 1.00 W.H. 16.00 W.P.	$ 1.50 W.H. 16.50 W.P.	$ 2.00 W.H. 17.00 W.P.	$ 2.50 W.H. 17.50 W.P.
60	$ 2.69	$ 4.91	$ 7.13	$ 9.36	$11.59
70	9.36	11.58	13.81	16.03	18.26
80	16.04	18.26	20.48	22.71	24.94
90	22.71	24.94	27.16	29.39	31.61

* The cost of disposing of the residual stand is generally higher ($20 to $30 per acre), and net value would then be much lower than values shown here.

† Western hemlock.

‡ Western white pine.

pine stand at 40 years.[5] As defect in the understory increases, its value decreases. An understory that is 40 per cent or less defective is as valuable as a seedling white pine stand at 40 years. It is obvious that for stands with a high percentage of defect there is no choice but to use silvicultural methods that will replace the defective timber with a new stand. In those stands, when the western white pine is overmature, the cost of artificial regeneration usually is from 60 to 95 per cent of that of natural regeneration, since the seed trees required for the latter can seldom be reclaimed later. If the white pine is mature natural regeneration is probably more economical than artificial regeneration because the pine with its increased volume can be cut later. The cost of disposal of defective fir and hemlock varies with the volume of this material and the proportion of it that must be disposed of, but in any case the cost is high, ranging, on the average, from $23.00 to $38.00 per acre (Davis and Klehm 1939).[6] Nelson (1939) questions the justification of such high expenditures and points out that on a 100-year rotation the net loss under complete liquidation

[5] The white pine stumpage values used here are probably higher than is justified. This is true also of the stumpage values of the other species. Obviously a prediction of this sort is very hazardous.

[6] Part of this cost is for slash disposal, which is discussed more fully on p. 406.

would be $441.61 per acre. He further predicts that even the most optimistic estimate of return under selection cutting would be approximately 1 per cent on the investment.

Cultural Operations in Immature Stands. As previously shown (p. 393), the production of a high-value western white pine crop generally depends on treatment of the young stands. Markets for small materials are so limited that intermediate cuttings generally represent an investment in the growing crop. It is evident, therefore, that treatments applied when stands are young are most likely to be financially feasible. Two cleanings between the tenth and twentieth years are usually a good investment, especially on good sites in accessible sections. The economic feasibility of thinning and pruning has not been demonstrated. Crown thinnings in which only prospective final crop trees are released probably offer the greatest promise for increasing growth at relatively low cost. The practicability of pruning has not been demonstrated.

Application of Methods

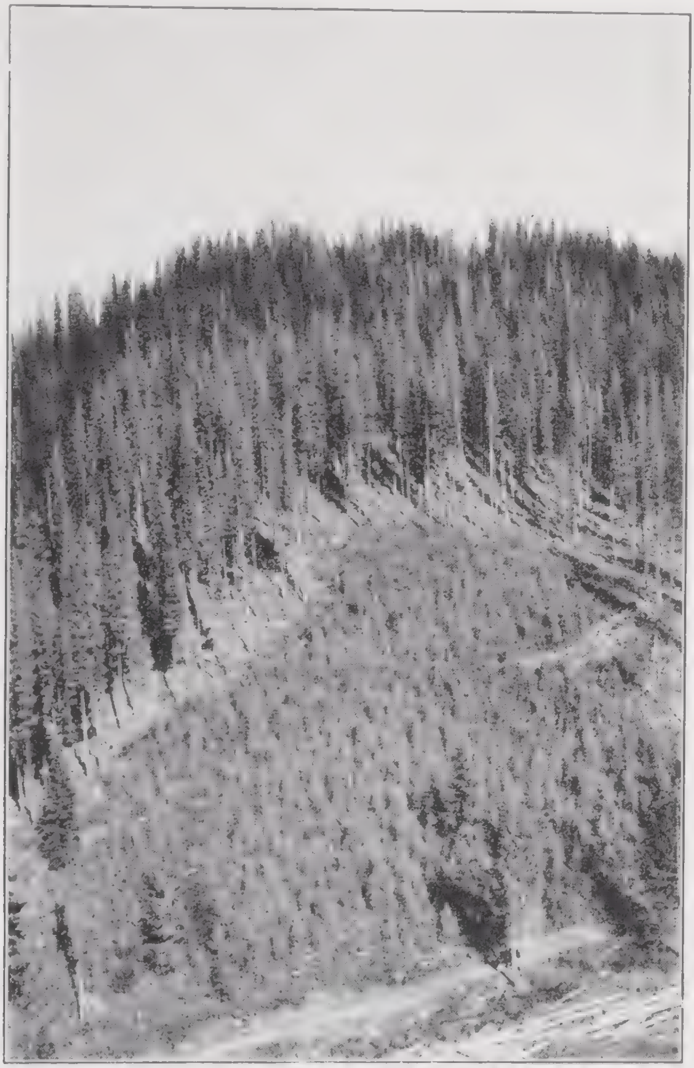
The stands of western white pine are so diverse that a great variety of silvicultural methods is applicable. The methods applicable to each stand condition will be dicussed in order.

Mature and Overmature Stands. The method that is best suited to any particular stand is determined by the structure of the stand, particularly with regard to composition and soundness and the character of the site on which it occurs (Haig, Davis, and Weidman 1941).

Clearcutting. This method is best suited to (1) even-aged stands composed principally of merchantable trees and (2) defective overmature stands, only a small portion of which is or ever will be merchantable (chiefly stands containing much defective hemlock and grand fir), on north, east, and the less-exposed west slopes (Fig. 68). If the stand is so constituted that cutting can be confined to strips 200 to 400 feet wide or to small irregular patches, reliance can be placed on natural regeneration if the adjacent stands can be left uncut until adequate reproduction becomes established (from 1 to 10 years), or they can be cut by a system of partial cutting. If this is not feasible, planting is necessary (as outlined under "Planting," p. 405). Only the merchantable timber should be cut for utilization; the defective or otherwise unmerchantable grand fir and western hemlock should be felled and the slash therefrom disposed of as outlined on p. 407.

Seed-Tree Cutting. This method is best suited to even-aged stands composed primarily of merchantable trees (chiefly stands 120 to 200

years old dominated by mature white pine), on north and east slopes and less-exposed west slopes and flats (Fig. 69). Two to six western white pine seed trees per acre should be retained, these supplemented

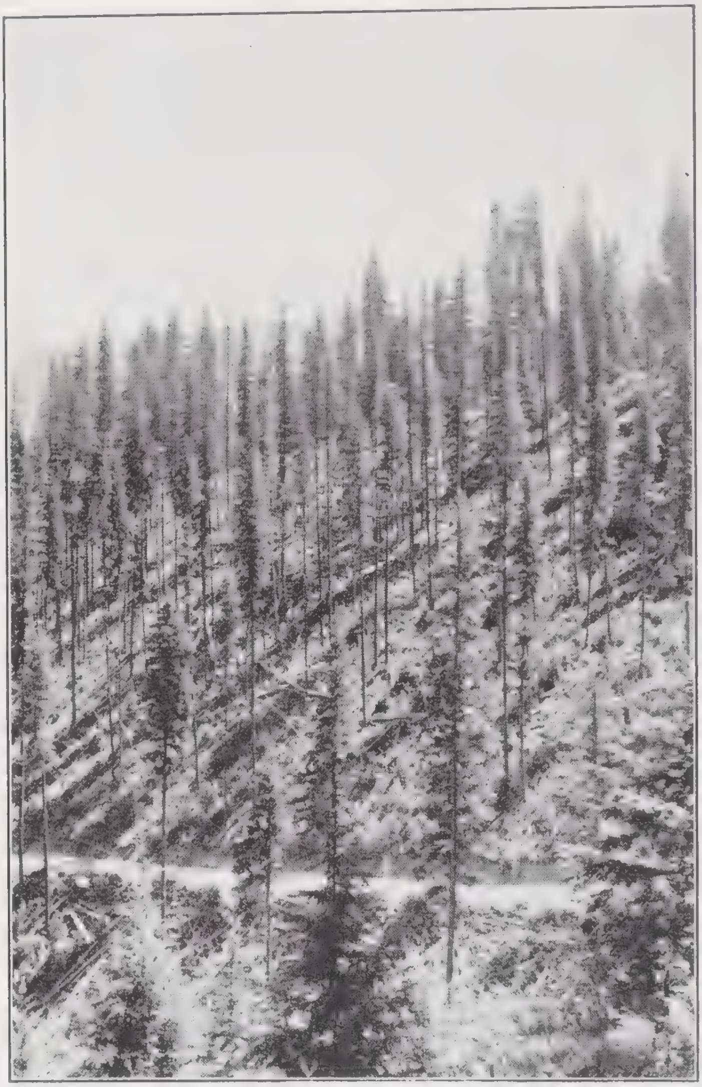


Photograph by U. S. Forest Service.

Fig. 68. Clearcutting is adapted to old-growth western white pine stands composed of mature and overmature pine and defective hemlock on protected sites.

by a few trees of other species, principally western redcedar and western larch, the latter as a fire-insurance tree. Seed trees should be thrifty, vigorous, full-crowned dominant trees, preferably 16 to 24 inches d.b.h., although an occasional tree only 14 inches d.b.h. is not objectionable. Any unmerchantable material should be felled, and the slash from it

disposed of as outlined on p. 407. Girdling is not objectionable where the fire hazard is very low. The seed trees may be cut after repro-



Photograph by U. S. Forest Service.

FIG. 69. A seed-tree cutting in a 160-year stand of the western white pine type. The stand of hemlock and fir, numbering 30 to 50 stems per acre, was cut. A good stand of reproduction has become established. Contrast with Fig. 70.

duction is established, if economically feasible (not essential silviculturally).

Shelterwood Cutting. Shelterwood cutting is desirable in (1) well-stocked stands with a large number of trees of salable species below

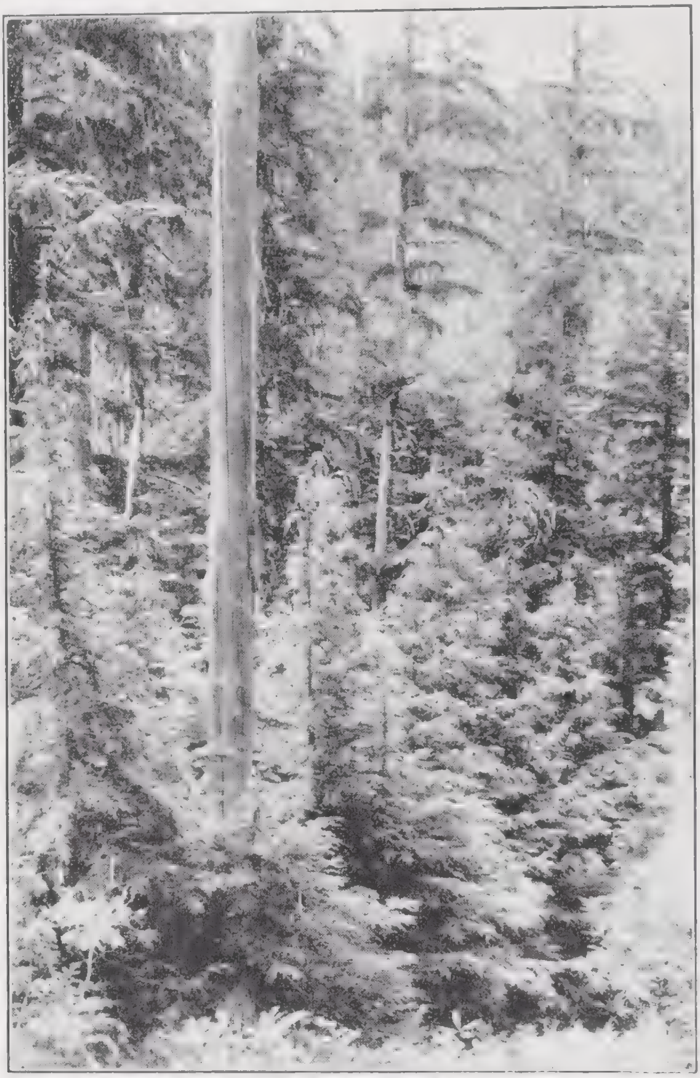
the lower diameter limit of merchantability (including stands 60 to 70 years old) and (2) stands containing a considerable number of sound species, unmerchantable at the time of cutting but that subsequently may become merchantable (fir and hemlock understories with less than 40 per cent defect), on any site (although least desirable on north and east slopes) (Figs. 70 and 71). All marketable trees, except seed trees of the type and number (or a few more) left in the seed-tree method, should be cut. Defective trees should be felled and their slash piled and burned (see p. 407). The second cutting (the removal cutting) can be made any time after reproduction is established and the residual stand becomes merchantable.

Selection Cutting. Selection cutting appears to have some merit on a limited scale in irregular, rather uneven-aged stands containing advance reproduction and immature trees, especially cedar, in addition to trees of merchantable size. It is not likely that selection cutting can be regarded as a permanent system for western white pine stands; after one or two cuttings it may have to be abandoned for some other method to prevent deterioration in stand composition. Trees to be cut should be selected on the basis of their silvicultural and economic desirability. By cutting western white pine to a diameter limit varying from 13 to 17 inches d.b.h. (based on economic considerations, with silvicultural considerations determining individual tree selection), the stands may be left in a productive condition. If occasional openings warrant it, a few seed trees should be retained. Western redcedar trees containing less than 30 feet of merchantable length ordinarily should not be cut.

Cultural Operations before Commercial Cutting. The application of cultural operations before commercial cutting in stands containing a considerable amount of defective timber that will not be cut for at least another 10 years seems to have merit, especially on south slopes. It should be possible thereby to regenerate the stand before commercial cutting. The technic should be the same as outlined for stand improvement after shelterwood cutting (below).

Cultural Operations after Commercial Cutting. Cultural operations are necessary immediately after cutting in stands cut by the shelterwood method and on much of the unburned cut-over land that was cut without any regard to silvicultural considerations. On areas cut by the shelterwood method partial disposal and, on unburned, previously unmanaged, cut-over land, either partial or complete disposal of the unmerchantable stand, depending on its condition, should be

applied. In stands of the latter type, where reproduction of high-value species has become established, the cutting should take the form of a liberation cutting.



Photograph by U. S. Forest Service.

FIG. 70. Although the overstory and understory of hemlock and fir was left in this white pine stand, cut 20 years ago, reproduction with a good proportion of western white pine has become established in the openings.

Complete disposal (applicable on clearcut areas and cut-over lands composed chiefly of defective trees or of sound trees with little or no anticipated future value) is primarily a slash-disposal operation and is, therefore, discussed under "Slash Disposal," p. 407.

Partial disposal (applicable chiefly to stands cut by the shelterwood method and old cut-over lands supporting a small volume of defective and unmerchantable timber) requires careful selection of trees to be felled, followed by disposal of the slash by piling and burning or swamper burning (see p. 407).

Photograph by U. S. Forest Service.

FIG. 71. Shelterwood cutting in mature western white pine stands on exposed sites gives the needed protection for reproduction.

On protected sites (northerly slopes) all defective and suppressed grand fir and western hemlock trees, together with very defective western redcedar trees, except four or five needed as seed trees, should be cut. Sound trees should be cut only when their removal is necessary to open the stand for the establishment of reproduction.

On severe sites (south slopes and exposed flats), fifteen to thirty trees per acre must be left, including some defective ones if necessary to reach the minimum.

Liberation cutting can best be done in conjunction with cleaning or thinning. "Wolf hemlock," defective grand fir, lodgepole pine, and western redcedar that suppress western white pine seedlings should be

cut.[7] Slash from felled trees may be lopped except where burning is necessary as a fire-protection measure (see p. 407).

Immature Stands. *Cleaning.* Cleaning is necessary in most reproduction and small sapling stands—chiefly in restocking burns, plantations, and cut-over lands cut 8 or more years before. If a young stand does not contain 1000 trees per acre, 250 of which are vigorous western white pine, cleaning is not recommended (Davis 1936). In applying a cleaning, trees, under the following circumstances, should be removed in any type of stand: (1) all lodgepole and ponderosa pine for a distance of 6 to 8 feet from better white pines, (2) grand fir and Douglas-fir more than two-thirds as tall as white pine for a distance of 6 to 8 feet from better white pines, (3) all western larch for a distance of about 8 feet from better white pines, and (4) Engelmann spruce as tall as or taller than white pine. Hemlock and cedar should be treated in accordance with density of overhead canopy. On east, west, south, and upper north slopes and flats with less than 30 per cent overhead shade, all hemlock as large as or larger than white pine for a distance of 4 to 6 feet from the better pines should be removed. In the presence of cedar, hemlock should be cut to favor cedar. On all sites supporting an overhead shade of more than 30 per cent, except lower north slopes, cleaning should not be attempted unless most of the overstory can be removed.

Thinning. Thinning is recommended for stands between 20 and 50 years old [8] that contain a large number of trees other than western white pine (Davis 1936). Crown thinning, to favor the vigorous, sound straight trees, should be applied. Intermediate and suppressed trees more than 3 or 4 feet from the crop trees should not be cut. Spacing after thinning should vary from 9 by 9 feet (500 trees per acre), for stands in which the trees range from 5 to 10 inches d.b.h., to 13 by 13 feet (250 trees per acre), for stands in which the trees range from 8 to 14 inches d.b.h. In selecting trees for retention uniformity of spacing should be given less emphasis than condition of tree and species. Although western white pine and western redcedar should be favored over other species when they are in equally good condition, poor trees of these species should not be selected in preference to well-formed

[7] Girdling may be permissible on areas of low fire hazard where less than fifteen trees per acre are involved. It should be done in spring or early summer (Brewster and Larsen 1925).

[8] Stands over 50 years old should not be thinned unless the material removed has a positive value.

thrifty trees of lower-value species. It appears at present that only one thinning during the rotation is feasible.

Pruning. Although an opinion based on limited study, it appears that pruning of sapling and small pole stands is practical (Davis 1936). The age of 25 years seems to be an ideal time to start it. The handsaw is best for low pruning; the pole saw is apparently superior to the handsaw-ladder method for high pruning.

Planting. Planting and direct seeding must be applied extensively if the vast areas of old burned cut-over land and old burns are to be made productive of timber. These types of reforestation have application also where it is not practicable to depend on natural reproduction after clearcutting (see p. 398).

If planting is to follow clearcutting, it should be preceded by slash disposal and other site preparation. A light fire should be allowed to pass over the area while unmerchantable trees are still standing. Some of the *Ribes* seed will be killed by such a fire, some will be devitalized, and the remainder will germinate. Three to 5 years later, the living and dead standing timber should be cut, after which a hot fire should be allowed to burn over the area. Such a fire will consume most of the light fuel and will kill the young *Ribes* plants and any remaining *Ribes* seed (Wellner 1946).

Western white pine is the most suitable species for reforestation on most sites, although on exposed areas, notably extensive flats, ponderosa pine can be used effectively. Although a 3-year (1-2) transplant of white pine was once regarded as the most economical stock (Wahlenberg 1928), more recent study does not demonstrate this. It appears that high-quality stock and care in handling stock and in planting are more significant (Schopmeyer 1940). Planting should be done preferably in spring, because survival will be greater than with fall planting. Spacing should be 7 by 7 feet on the poor sites, 8 by 8 feet on the better sites.

Spot sowing of western white pine, when properly applied, gives as good results in tree establishment as does planting (Schopmeyer and Helmers 1947). Spot sowing should be confined to north slopes and flats. Rodent control must be provided either by screening the seed spots or spreading poison over the area 1 week before seeding. Eight hundred spots per acre should be sowed in the fall with approximately twenty seeds per spot. Equally good results can be secured in sowing western redcedar without any precautions against rodents. Experiments in thinning seed spots do not prove or disprove the need for thinning after 9 years.

Slash Disposal

Slash in Relation to Fire

Slash resulting from heavy cutting of the old-growth forest is large in volume and adds to the acuteness of the naturally high fire hazard of the region caused by frequent electrical storms in summer, the low midsummer precipitation and humidity, the large quantity of debris—other than slash—on the forest floor, high, dry, summer winds, and inaccessibility (Gisborne 1936). Cutting increases the inflammability of the forest by greater exposure and resultant drying of the site (Jemison 1934). Decomposition of the slash is slow, and the slash hazard is not entirely dissipated in less than 15 years. Clearcut areas, unless broadcast burned, constitute the greatest hazard. Lyman (1947) believes that research will ultimately demonstrate that there is considerable variation in the fire hazard of different sites.

Slash resulting from cleaning, thinning, and liberation cutting is relatively light and constitutes a fire hazard for only a few years.

Ecological Effects of Slash and Slash Burning

Heavy slash interferes with the establishment of reproduction. A moderate volume of slash probably has a neutral effect. Slash burning, by consuming at least a part of the duff, thus exposing the mineral soil, thereby increases the germination of western white pine, western redcedar, and western hemlock seed (Larsen 1924). If the site is shaded, seedling survival is also greatest on burned surfaces. The ash from burned slash fertilizes the soil, thus stimulating seedling growth.

Economic Considerations

Slash disposal costs are high for old-growth forests, but the high value of the crop and the past experience with fire on slash-covered areas demonstrate that heavy expenditures for this operation are justifiable. Piling and burning can be accomplished for approximately 0.75 to 0.90 man-hours per thousand board feet of timber cut (Billings, Rettig, Baggs, and Rapraeger 1942). This appears to be the only method that effectively reduces the fire hazard and conserves the forest growth on areas cut by the seed-tree, shelterwood, or selection method. Broadcast burning at an average cost of about $30.00 per acre (includes felling of defective trees) appears to be the cheapest and most effective means of reducing the fire hazard on clearcut areas (Davis 1936).

Costs of partial slash disposal following cleaning, thinning, and liberation cutting are not available.

Application of Methods

The method of complete piling and burning, the burning to be done in the fall, is recommended for all cut-over old-growth stands except those that are clearcut (Kock and Cunningham 1927, Larsen and Lowdermilk 1924) (Fig. 72).

Broadcast burning is recommended for clearcut areas. To secure a safe, effective burn small details must be observed from the start, beginning with the felling of the defective trees, to the finish. The following details must be regarded in preparing the area for burning (Davis 1936):

1. The area must have a regular boundary composed of any available natural features. It should extend slightly over the ridge top on a slope, and 100 to 150 feet across the canyon when only one side of a narrow canyon is cut.
2. Trees should be felled in such a manner that slash will be bunched. All slash on a strip 50 feet wide along the edge of the cut-over area usually should be lopped and thrown toward the center of the site. If slash is to be burned while partly green, much of it should be lopped.
3. All snags must be cut that are over 6 feet tall in, and extend 75 to 100 feet outside, the cut-over area.
4. On a 20-foot strip surrounding the area all inflammable material should be cleared.

Burning should not be attempted unless duff moisture is above 10 per cent, and preferably it should be above 13 per cent. This condition is most likely to materialize between 4 and 7 P.M. on a calm, clear day, 2 to 3 days after the first fall rain of one-half inch or more (Davis and Klehm 1939).

For areas of more than 10 acres on slopes under 20 per cent and on flats, "center firing" is best. By this method several fires are started in the center of the area, and then, when these have generated a large volume of heat, another series of fires—these should be pulled toward the center—should be started 100 to 200 feet from the edge of the cut-over area.

For a large area with a slope over 20 per cent, strip burning is advisable. The first fires should be set at the extreme upper edge. When the first 100- to 200-foot strip is well burned out, fires should be set 100 to 200 feet down the slope. This process must be repeated until the entire slope is burned over.

For small areas (1 to 2 acres), "edge burning," whereby fires are started at the edge and allowed to burn toward the center, is best.

Photograph by U. S. Forest Service.

Fig. 72. When hemlock and fir are felled after the western white pine is cut, the slash of all trees must be piled and burned.

Slash resulting from cleaning needs no treatment except on 35-foot strips along roads and trails that are designated as fire breaks, where it should be pulled into the road and burned.

Slash from thinning should be burned for 100 feet on each side of all highways, 50 feet on secondary roads, and 25 feet on truck trails

or wood roads. In a large thinned area additional burning may be advisable on 20-foot strips 300 to 400 feet apart.

Slash from liberation cutting should be lopped. Piling and burning are necessary along roads where the slash may interfere with reproduction and where more than 20 trees per acre are cut.

Disease and Insect Problems

Ecological Basis

The *brown stringy rot,* caused by the Indian paint fungus, is responsible for the serious trunk rot in grand fir and western hemlock (Hubert 1931). Infection occurs at about 40 years, and at 100 years 25 per cent of the volume of the average western hemlock is decayed. In old-growth trees, rot in the heartwood may extend the entire length of the trunk and into the larger branches and roots. Cutting serves as a sanitation measure chiefly because it removes defective trees, as evidenced by the occurrence of brown stringy rot in 66.7 and 62 per cent of the western hemlock and grand fir trees, respectively, in a cut-over stand as compared with 96.6 and 96 per cent, respectively, in an uncut stand (the hemlock was 70 to 80 years old, the fir somewhat younger) (Weir 1919).

The *yellow ring rot,* caused by the brown cedar poria, is prevalent in the butt and root sections of mature and overmature western redcedar trees. In addition to destroying much merchantable wood, the rot is the cause of windbreakage and windthrow (Hubert 1931). Several other rots cause damage, but they are far less important than those already mentioned.

The *white pine blister rust* is commonly found on currant and gooseberry bushes; and, although not of serious proportions now, it is found quite generally on white pine, thus constituting a major threat to the continued production of white pine. Since the success and cost of control depends on the ease with which the various species of the genus *Ribes* can be permanently eradicated, knowledge of the ecology of the *Ribes* is significant to an understanding of the problem. Re-establishment of *Ribes* after its initial eradication must come chiefly from seed that is stored in the duff. Shade and litter discourage the germination of the seed. Disturbance of the duff stimulates the germination; thus, unless tree reproduction follows cutting promptly, *Ribes* is likely to become established wherever the litter is disturbed and is not destroyed by slash disposal. A thorough broadcast burn destroys all, or nearly all, the *Ribes* seed in the duff (Davis 1936).

Pole blight, the causative agent of which has not been determined, is doing severe damage in white pine stands from 40 to 100 years of age. Some areas show a 100 per cent kill. In 1947 it was estimated that 70,000 acres were damaged.

The *mountain pine beetle,* an enemy of the western white pine, is present in endemic form in practically every white pine stand. Weakened or decadent trees (the cause of this condition may be overmaturity, fire scorching, lightning, or other factors) are infested during endemic stages, causing a loss of about 1 per cent of the timber volume annually (Craighead, Miller, Evenden, and Keen 1931), thus, in mature stands, often offsetting the growth of the stand. Suddenly endemic attacks may become epidemic, at which time any types of trees are infested singly or in groups of 75 to 100 trees, causing an annual loss of 3 per cent or more of the merchantable timber. Epidemics are generally short-lived, subsiding naturally.

Economic Basis

The combined forces of all diseases and insects could eventually destroy the entire forest crop, and are at present making serious inroads into the merchantable timber. Successful timber growing depends, therefore, in part on disease and insect control. The cost of felling defective timber and disposing of the slash therefrom is outlined on p. 406. The cost of blister rust control at \$2.00 per acre initial cost and \$0.08 to \$0.10 annual maintenance cost will, at 3½ per cent interest, amount to \$87.00 on a 100-year rotation or \$3.50 per thousand board feet of timber grown (Neff 1933). With stumpage values of \$200 to \$300 per acre, Neff regards the investment as economically sound. Unfortunately the actual cost over a period of years has been about \$4.00 to \$6.00 per acre.

Control Methods

A rotation of 80 to 100 years for western hemlock, grand fir, and western redcedar and disposal of defective old-growth timber (see p. 397) should reduce the danger from brown stringy rot and yellow ring rot to a minimum.

Control of the white pine blister rust resolves itself into two types of work: (1) eradication of established *Ribes* and (2) application of management measures, including slash disposal, which will reduce the amount of *Ribes* in new stands. The latter is discussed on p. 406. To accomplish *Ribes* eradication on the most economical basis, Billings

(1947) recommends that the work be done on a priority basis. He advises giving first attention to large areas of high site quality, especially young stands and currently logged areas. This is in line with Swanson's (1939) recognition of different degrees of *Ribes* population in four different ecological types. Chemical eradication is suitable for some species of *Ribes*, but mechanical eradication must be applied to others (Offord, Van Atta, and Swanson 1940).

The application of measures to control the mountain pine beetle is most practical just before the infestation develops into the epidemic stage (Craighead, Miller, Evenden, and Keen 1931). Felling of the infested trees, followed by peeling and disposal of their bark, has proved ineffective and is therefore no longer recommended (DeLeon, Bedard, and Terrell 1934). The insertion into the sap stream in late summer or early fall, not more than 90 days after infestation, of a copper sulphate solution is recommended as the most effective and economical method (Bedard 1938).

Control of Animal and Logging Damage

Control of livestock is concerned only with cut-over and burned-over areas of the western white pine type because grazing is restricted to these classes of land. Careful regulation is essential to prevent damage to reproduction, since sheep are generally involved.

Power logging, used to only a limited extent, must be carefully regulated and supervised if logging damage is to be adequately controlled. Other methods of logging—a combination of horse logging and chutes is most extensive—present no special problems. Care and close supervision are the key to controlling damage.

LARCH–DOUGLAS-FIR TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest

Importance.
- Area—Major, especially in Montana.
- Commercial Value—Moderate.

Sites Occupied—Comparatively dry sites at elevations of 3000 to 5500 feet (Larsen 1930).

Associated Species.

Major—Western larch and Douglas-fir (sometimes exclusively).

Minor—Western white pine, ponderosa pine, lodgepole pine, grand fir, western redcedar, Engelmann spruce.

Place in Succession—Temporary type. Climax type is believed to be Engelmann spruce and Douglas-fir, but development to climax type is very slow.

The grand fir–larch–Douglas-fir type differs sufficiently in composition from the larch–Douglas-fir type to be recognized as a distinct type. It occupies the cooler mountain sides. The major role of the grand fir and the substitution of the western hemlock for western redcedar as a minor component distinguish the former from the latter type. Problems in management of the two types are similar.

The ponderosa pine–larch–Douglas-fir type occupies sites that are intermediate between the dry ponderosa pine sites and the moister larch–Douglas-fir sites. The three species that give the type its name are its major species. Western white pine, grand fir, and lodgepole pine are minor components. It is probably a subclimax type of fire origin, and it is slowly succeeded by the interior Douglas-fir type (Committee on Western Forest Types 1945).

Larch–Douglas-fir forests generally originated after fire, some of them as even-aged stands; but 80 to 90 per cent of the old-growth forests are now uneven-aged, generally with three distinct age classes present. The existing stands are mostly mature to overmature, the larger trees averaging 2 to 3 feet in diameter and 100 feet in height. Average stands produce 10,000 to 20,000 board feet per acre. They are moderately dense and support a sparse cover of vegetation composed of only a few species. Cut-over stands vary from the fairly well-stocked, selectively cut stands on the national forests to the sparsely stocked, essentially clearcut stands on privately owned lands.

Stand Regeneration and Development. The quantity and composition of advance reproduction varies widely with stand conditions, western larch being present only in thin stands, Douglas-fir being fairly abundant in stands of medium density, and grand fir and Engelmann spruce being the chief reproduction in dense stands. Seldom is advance reproduction sufficiently abundant to form an adequate reproduction stand after cutting.

Some seed is borne nearly every year by mature trees of at least one of the species. Douglas-fir is the most prolific. A cut-over forest is a more favorable site than an uncut forest for the establishment of western larch and Douglas-fir seedlings because of less competition

(Larsen 1916). Both species are partial to a mineral soil seed bed, a fact that accounts for the superior seedling establishment on burned spots, such as areas where slash piles have been burned. To compete successfully with reproduction of other species, western larch and Douglas-fir seedlings must have a moderately open site. Larch, because of its rapid height growth, has an advantage over other species in the early struggle for dominance of the stand on an open site. Douglas-fir ranks next in this respect. As the density of the reserve stand increases, the site becomes increasingly less favorable to survival of western larch and Douglas-fir seedlings and more favorable to Engelmann spruce and grand fir seedlings.

Windfall. Uprooting of trees is uncommon in uneven-aged stands. Tall timber on moist sites is very susceptible to windthrow, especially when trees are more or less isolated as a result of cutting. Windbreakage is most prevalent in defective grand fir trees.

Economic Basis

The complex economic problems of the western white pine type overshadow the economic problems of the larch–Douglas-fir type to such an extent that little study has been made of the latter. The differential value of species is not great. Western larch and ponderosa pine are the most valuable, with Douglas-fir and Engelmann spruce next in order. The other associates have little or no commercial value. There is a strong demand for western larch and Douglas-fir for cross-ties and mine timbers. The marginal tree for cross-ties of these species on one operation was 13 inches d.b.h. (Anderson 1937).

There are only minor differences in the rate of growth of western larch and Douglas-fir on cut-over land—average growth in diameter being approximately 1 inch in 10 years. Engelmann spruce grows after cutting an average of 1.5 inches in diameter in 10 years. Increase in volume of cut-over stands on good to fair sites occurs at a rate of 100 to 200 board feet per acre annually, as shown in Table 30.[9] The large increase in increment between the third and fourth decade is due to the fact that many trees previously too small to be measured in board feet attain the required size during this period. Growth on poor sites is much slower than that for better sites shown in Table 30, being as low as 12 to 54 board feet per acre per year on the poorest areas (Miles 1941). Growth on poor sites shows the same relationship to

[9] Taken from *Applied Forestry Notes*, published by Northern Rocky Mountain Forest and Range Experiment Station.

volume of reserve stand and elapsed time after cutting as on the better locations.

Application of Methods

Most of the old-growth forests can be reproduced most effectively by partial cutting. On the average 10 to 30 per cent of the volume of the merchantable stand can be retained to advantage as a reserve stand (Division of Timber Management 1932) (Fig. 73). From acre to acre the amount that can be reserved varies widely. Seed trees must be left as needed where cutting is heavy. If the overstory is largely mature and overmature and there is beneath it a full stocking of young trees, clearcutting of the overstory is advisable.

TABLE 30

The Average Increase in Board-Foot Volume of Cut-Over Larch–Douglas-Fir Forests on Good to Fair Sites

Reserve Stand Volume	Volume at 10-Year Periods after Cutting			
	10 Years	20 Years	30 Years	40 Years
Board Feet	Board Feet			
1,000	1,900	3,600	5,800	8,650
2,000	3,200	5,250	7,450	10,300
3,000	4,300	6,500	8,600	11,500
4,000	5,300	7,550	9,600	12,500

For even-aged mature stands, seed-tree cutting, leaving three to six seed trees per acre, is recommended. Here as well as elsewhere, if seed trees are needed, western larch should be the first choice and Douglas-fir the second choice on the average site. On sites to which they are well adapted western white pine and ponderosa pine should be favored for seed trees as well as in other tree selection.

Diseased, insect-infested, and otherwise defective trees should be cut as extensively as practical for stand improvement.

Immature even-aged stands, when easily accessible to fence post, pole, or mine timber markets, should be thinned. Low thinning is the practice recommended.

Slash Disposal

The volume of, and fire hazard created by, slash resulting from the cutting of old-growth timber vary widely, depending on the volume and composition of the stand. Western larch produces less slash per unit of timber than its associates, and its slash is less hazardous during the first few years because the needles drop soon after cutting. On tie cuttings, which constitute the bulk of the cutting, the slash volume is so large that it contributes a serious fire hazard that is not entirely gone for 15 years. Slash is seldom dense enough to have other than a neutral effect on reproduction. On the most hazardous areas the method of complete piling and burning of slash is recommended. Particularly where the cut of timber is chiefly western larch, partial piling and burning can be substituted.

Photograph by U. S. Forest Service.

FIG. 73. Selection cutting in mature stands of western larch and Douglas-fir usually removes 70 per cent or more of the merchantable timber. The slash lies here as it fell.

Disease and Insect Control

Western larch is severely infected with *mistletoe* in some areas. Control of the disease depends on judicious removal of the most severely infected trees in cuttings.

The *Douglas-fir beetle* has been attacking mature Douglas-fir trees for many years, but only since 1930 has the infestation caused serious loss of merchantable timber (Craighead, Miller, Evenden, and Keen 1931). Too little is known about its control to warrant any recommendations.

The *mountain pine beetle* infests and kills lodgepole pine, a matter of little concern because of the scattered occurrence and low commercial value of the lodgepole pine.

Although the *Douglas-fir tussock moth* has not caused extensive damage in the larch–Douglas-fir forests, the severe infestation that developed in Douglas-fir and grand fir forests in northern Idaho in 1946 suggests that it presents a potential threat to the larch–Douglas-fir forests. Aerial spraying with DDT solution in 1947 was sufficiently successful to indicate that control by this method is possible.

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12 · Lodgepole Pine Region

DESCRIPTION AND HISTORY

Location and Landownership

The lodgepole pine region, confined to the commercial range of the lodgepole pine, centering around Wyoming, covers a large area, but included within its boundaries are extensive sections of non-timber land. It includes most of western Colorado, all of Utah, except a strip in the southern part of the state, central and northeastern Nevada, southeastern Idaho, all of western Wyoming, and a narrow strip in central Montana east of the Continental Divide (Fig. 1). The forests are limited chiefly to altitudes of 6000 to 10,500 feet.

The timbered land comprises 23,000,000 acres, 93 per cent of which is publicly owned (Thompson 1929). Of the entire forest area, 87 per cent outside of national parks is national forests, 5 per cent is public domain and Indian reservation, and 1 per cent is state-owned land. The area of federal forest lands is being increased by the Federal Government's policy of transferring grazing land to the states in exchange for timber land.

Physiographic Features

Numerous high peaks (50 above 14,000 feet and several more above 13,000 feet) with steep slopes and a generally broken, rugged topography characterize the northern and central Rocky Mountains, of which the lodgepole pine region is a part. The southwestern portion of the region is unique for its high plateaus from which rise several isolated mountain ranges, attaining an altitude of 10,000 feet or more.

The region is cut by numerous streams, many of which are large. Drainage is chiefly to the northeast and south. In Wyoming the Yellowstone River, flowing northeast and finally emptying into the Missouri River, is the biggest stream. The Green River passes through Wyoming and Colorado, flowing in a southerly direction, and finally

empties into the Colorado River. A portion of the northwestern part of the region is drained by the Snake River, which eventually empties into the Columbia River and thence into the Pacific Ocean. The streams are well distributed, and the bulk of them are sufficiently large to be of value in transporting forest products.

The soils are variable, but nearly all are characterized by shallowness and rockiness, features that make their productive capacity low. Sandy loam is the predominating class of soil. Only along stream bottoms where soil from the upper slopes has been deposited are the soils deep.

Climatic Features

The climate is characterized by a moderate to light precipitation, a rather dry atmosphere, a short growing season, heavy snows in winter, and fairly strong winds at the higher altitudes.

Much of the region has a mean annual precipitation of 18 to 20 inches (Weather Bureau 1926). Precipitation increases with altitude, some of the high points receiving more than 30 inches annually. It is fairly well distributed, although the months of June, August, and September are usually rather dry. A large proportion of the precipitation occurs from November through March in the form of snow. The amount of snowfall varies greatly with altitude, some of the higher points having an average annual fall in excess of 200 inches, whereas some of the points at low altitudes have only 30 inches. At the high altitudes, snow stays on the ground continuously from October to late May or early June.

The relative humidity is comparatively low. Even during the more humid seasons it is normally between 50 and 60 per cent. During the summer months average humidity at noon is 35 to 40 per cent. Frequently, however, it drops to 15 or 20 per cent.

The summers are short and cool at the higher altitudes. Light frosts occur often during the summer months, sometimes for several consecutive days. The mean maximum temperature for July, the warmest month of the year, ranges from 58° to 87° F. Occasional temperatures above 100° F. are on record.

Winter is uniformly cold and long. The mean minimum temperature for January, the coldest month of the year, ranges from −5.8° F. in the coldest sections to 29° F. in the warmest sections (Weather Bureau 1926). Continued cold causes the snow to lie on the ground all winter at the higher elevations.

The growing season is short. The period free of killing frosts varies from only 45 days at the high altitudes to 5 months at the lowest.

Nearly every electrical storm is accompanied by precipitation, and so these storms are not significant in starting forest fires.

The prevailing winds, from the west and southwest, average from 5 to 10 miles per hour (Weather Bureau 1926). The maximum wind velocity on record is 52 miles per hour.

Development of Lumbering

Cutting of timber in the lodgepole pine region began shortly before 1875. Most of the early cutting was done to supply the various wood products needed locally in the development of mines and railroads. In later years lumber was produced for shipment outside the region, but logging has never developed on an extensive scale. Few operations cut more than 5,000,000 board feet annually. Most of the cutting is for special products, such as mine props, telephone poles, and railroad ties.

The region is characterized by extensive areas of lightly cut and untouched virgin and old second-growth timber, which at the present rate of cutting will not be cut over for several centuries.

Effect of Past Practices

The early cuttings, which were on private lands and public domain, removed almost the entire forest cover over limited sections and left a large quantity of debris on the ground after logging. Since no particular effort was made to protect this land, most of it burned. Rarely were any steps taken to suppress the fires, with the result that extensive areas were denuded. Much of the denuded land, ultimately added to the national forests, has restocked naturally, but 1,230,000 acres still support little forest growth. The extent to which the burns have restocked was influenced by the composition of the original forest, the abundance of seed trees, exposure, cover, and soil type (Stahelin 1943). Where lodgepole pine was a part of the original stand, restocking occurs more readily than where aspen, spruce, or fir made up the stands. Restocking of areas originally occupied by spruce and fir has been especially slow because sedges, grasses, and other low vegetation take possession of the site and build up such a dense turf that trees may not invade for centuries. Numerous seed trees (at least ten per acre), north exposures, and a Vaccinium cover create conditions

favorable to restocking. Some 42,000 acres of successful plantations had been established in Wyoming and Colorado at the end of 1947. A small-scale program of 1000 to 2000 acres per year has been carried on by the Forest Service for several years.

After the timberlands of the region were set aside as national forests, extensive destructive cutting was stopped. Small areas of privately owned lands continued to be cut heavily and frequently, as in the past. On the average cutting operations, it is often not possible to utilize small trees, and so, if the cut-over area is not burned, the residual trees develop into a new crop of tie material in two or three decades. Owners of private lands usually recut their forests as soon as a few trees have grown to tie size. The limited cutting on state lands has been more conservative, particularly in recent years since the work in some states has had Forest Service supervision. Cutting on national forest lands has been fairly conservative. The object of cutting has been to maintain a forest cover adequate to protect the watersheds and to provide a second cut in a reasonable length of time. This practice has allowed cut-over land to restock successfully.

THE FORESTS AND THEIR MANAGEMENT

Three major forest types, the lodgepole pine, the Engelmann spruce–alpine fir, and the Douglas-fir, make up the major part of the forest land. Smaller areas of woodland and ponderosa pine types, similar to the same forest types of the southwest ponderosa pine region, are fairly common in the southern part of the region.

LODGEPOLE PINE TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest

Importance.
- Area—Major.
- Commercial Value—Moderate.

Sites Occupied—Chiefly burned sites between 6000 and 9500 feet, reaching best development in Wyoming at altitudes between 7500 and 9000 feet.

Associated Species.
- Major—Lodgepole pine, pure or predominant. Any one of several species may be major or minor associates.

Minor—Douglas-fir, Engelmann spruce, alpine fir, grand fir, ponderosa pine, western white pine, western larch, aspen.

Place in Succession—A subclimax type that, over extensive areas, is so firmly established that its replacement is very slow. The type may be climax on some sites. It may be replaced by a Douglas-fir or Engelmann spruce–alpine fir type (Committee on Western Forest Types 1945).

The younger lodgepole pine forests are generally even-aged, whereas overmature stands are mostly uneven-aged—the trees in a stand often varying as much as 200 years in age and 15 inches in diameter. Mature and immature pole stands occupy the largest area, the former probably being the original forest on permanent lodgepole pine sites, and the latter probably being second-growth forest seeded in on burned sites, some of which is not a permanent lodgepole pine site. There are limited areas of overmature and sapling stands. Because of the general overcrowding, the trees lack vigor and often have an unthrifty appearance. Small areas of denuded land are scattered through the forest.

Timber volumes are not large, the average for mature and overmature stands being 10,000 board feet per acre. Some of the best stands in Wyoming and Colorado yield 25,000 board feet per acre.

Stand Regeneration and Development. Reproduction in the uncut mature forest is very sparse, being confined mostly to open spots in the stand. Engelmann spruce and alpine fir seedlings are generally most abundant, because they are better able to survive under the characteristically dense canopies than other species. Rarely is there enough advance reproduction to provide a satisfactory nucleus for a new crop.

The frequent heavy seed crops that characterize lodgepole pine insure an abundance of seed in any lodgepole pine forest. From 1 to 7 pounds of seed per acre are borne almost annually (Bates 1930). Since lodgepole pine seed is retained in the cones for long periods—sometimes for 10 to 12 years after the cones fall—there is, at all times, at least a moderate quantity of seed on the forest floor.

The combination of a partial canopy, logging slash left on the ground, and exclusion of fire from the stand is best for the establishment of a lodgepole pine reproduction stand of desirable density (Bates 1930; Bates, Hilton, and Krueger 1929; Clements 1910). Only a part of the seed is released from the cones under these conditions, thereby minimizing the danger of overstocking. Lodgepole pine seedlings make

their best growth where all the tree canopy is removed, but their growth under a partial canopy is sufficiently rapid to prevent complete domination of the stand by the associated species.

Lodgepole pine's chief associates, Douglas-fir, Engelmann spruce, and alpine fir, reproduce best under the same conditions that favor a lodgepole pine stand of desirable density. Natural development of a partially cut stand favors these species over lodgepole pine because of their greater tolerance, whereas natural development of a clearcut area favors lodgepole pine because of its superior rate of growth.

TABLE 31

Description of the Characteristics of Tree Classes for Lodgepole Pine

Vigor Class	Crown Area	Crown Length	Crown Vigor
A	30 per cent or more of the "extreme maximum" outline of vigor class *A*	50 per cent or more of bole length	Dense, full, of good color, and pointed
B	Usually more than 30 per cent but less than 50 per cent of the "extreme maximum" outline of vigor class *A*	Usually more than 50 per cent but less than 60 per cent of the bole length	Moderately dense, of good color, pointed to slightly rounded
C	17 to 30 per cent of the "extreme maximum" outline of vigor class *A*	40 to 50 per cent of bole length, except for trees with distinctly better than average vigor, for which a minimum of 20 per cent of the bole length is sufficient	Sparse, bunchy, color poor, never pointed
D	All live trees of less vigor than class *C*. Includes trees with *A*, *B*, and *C* outlines but with dying tops or stagheads.		

The development of the reserve stand after cutting, particularly its growth, is dependent on the condition of and amount of release given to the individual trees that comprise the stand. In this connection the tree classification developed by Taylor (1939)—the characteristics of each tree class are shown in Table 31 and Fig. 74—is significant.

The rate of growth of the tree classes, assuming that the amount of release is the same in all cases, is in the order of their arrangement in Table 31 (class *A* making the fastest growth). Amount of release given a tree in cutting affects its rate of growth following cutting. Growth of a released tree is greatest when one tree of competing size

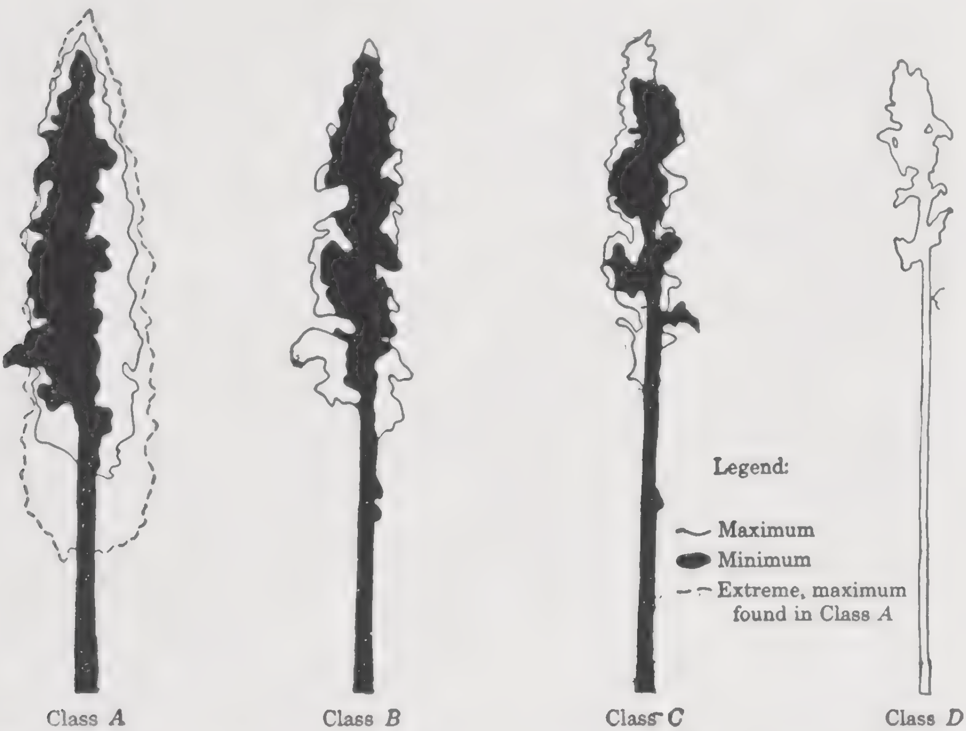

FIG. 74. Tree classes for lodgepole pine (reproduced from drawing by R. F. Taylor, Rocky Mountain Forest and Range Experiment Station).

is removed in each of four quadrats of a circle 40 feet in diameter. The removal of more than one tree per quadrat does not cause additional increase in growth. The best growth of the reserve stand occurs when a maximum number of the most vigorous trees, released on as many sides as practical, is retained.

A reserve stand of less than 3500 board feet per acre is a great windfall risk (Taylor 1939).

Windfall. Its natural habit of developing a shallow root system and the restricted lateral development of its root system imposed by the crowded stands make lodgepole pine very susceptible to windfall, especially when the stand is opened by cutting. Trees isolated before

cutting or of short stature withstand windfall best. The associated species, except Engelmann spruce, are reasonably windfirm.

Economic Basis

Utilization and Marketing Problems. Effective utilization is limited by the inferior quality and small size of the timber, the scarcity of industries, and the limited local markets. Lodgepole pine, because of its utility for a variety of products such as railroad ties, telephone poles, mine props, and poles, finds a ready market (Mason 1915*b*). The mine timber and prop market, although limited in size, is particularly significant because it provides an outlet for the small materials (derived from tops of large trees cut for ties and from small trees). Trees containing less than two cross-ties cannot be utilized profitably because of the large waste in cutting.

Douglas-fir and ponderosa pine, in general, yield low-grade lumber and are therefore better used for railroad ties, for which they are well suited.

Growth and Rotation. The growth potentialities are indicated by the growth of partially cut stands. Increment varies with the volume of the reserve stand, the tree classes that compose the reserve stand, and the elapsed time after cutting. Mean annual gross increment per acre varies from 53 board feet 60 years after cutting on a reserve stand of 1000 board feet per acre to 169 board feet 40 years after cutting on a reserve stand of 8000 board feet per acre (Hornibrook 1940). Rate of growth declines steadily within 20 years after cutting. A reserve stand of 5000 board feet per acre operated on a 30-year cutting cycle seems to produce the most satisfactory growth.

Although a rotation of 140 years has been proposed for railroad ties, a shorter rotation can undoubtedly be used by applying thinnings in young stands.

Financial Aspects. The large number of small trees in some mature and overmature stands and the lack of an extensive market for small materials in some areas are limiting factors in economical cutting of the forests. Where markets for mine props and fence posts exist, the application of good silviculture has fewer economic limitations. Thinnings in pole stands is dependent on such markets.

Application of Methods

Saw-Log and Cross-Tie Stands. Two methods of cutting seem to meet the needs of existing stands reasonably well. For overmature

stands, clearcutting seems almost a necessity because they do not contain enough class *A* and *B* trees to form the basis for a reserve stand of sufficient volume to give protection against windfall. Clearcutting has the added advantage of discouraging the regeneration of alpine fir, and, when applied to scattered relatively small areas, it

Photograph by U. S. Forest Service.

FIG. 75. A two-cut shelterwood system in which the reserve stand is composed of about 5000 board feet per acre, chiefly of class *A* and *B* trees, is effective for lodgepole pine stands under 175 years.

seems to meet the requirements of fire control, wildlife management, and watershed protection (LeBarron 1947). To secure the best all-round results in management, clearcutting should be applied to groups, strips, or small blocks to meet the variable stand and site conditions. The chief objection to clearcutting is the overstocking of reproduction which usually follows. Where markets for material cut in early thinnings are not available, these dense young stands present a serious problem.

For mature stands under 175 years old, a two-cut shelterwood system is satisfactory (Fig. 75). Density of reproduction can be con-

trolled effectively by this system. Furthermore, enough trees of good vigor are available in these stands to make possible the retention of a reserve stand that can grow rapidly for a period of 10 to 15 years. A reserve stand of approximately 5000 board feet composed of a maximum number of fully released class *A* and *B* trees should be the goal. All class *D* trees should be cut. Class *C* trees that must be retained should be released on at least two sides.

Photograph by U. S. Forest Service.

Fig. 76. Young stands of lodgepole pine are usually so dense that stagnation takes place. Thinning increases growth and shortens the time required to produce tie timber.

Thinning in Pole and Sapling Stands. Thinning in immature stands is silviculturally desirable as a stimulus to growth—increased growth may be a deterrent to beetle attack (Fig. 76). Discretion must be used in the selection of stands to be thinned, ability to respond and financial considerations being the determining factors. If mine props or other small products can be marketed, healthy pole stands should be given preference over sapling stands in thinning plans. On the other hand, if no market for small material currently exists and there is little future prospect for such a market, sapling stands should be thinned ahead of pole stands because of the lower cost. In all cases, if markets for small materials are not likely to develop, thinning should

aim for satisfactory stand growth until the trees, without additional treatment, attain railroad-tie or telephone-pole size. This implies reasonably heavy thinnings with the following spacings in accordance with the average size of the trees in the stand: 6 by 6 feet when trees average under 8 feet in height; 8 by 8 feet when trees are 8 to 15 feet high; 9½ by 9½ feet when trees are 15 to 30 feet high (Woodhead 1934);[1] and 10 by 12 feet when trees average 8 inches in diameter (Thompson 1929). Spacing need be only approximate; superior trees should be selected at a sacrifice in spacing. Dominant and codominant trees should be given preference as crop trees. Trees infected with western gall rust or mistletoe (see p. 432) should ordinarily be removed except when urgently needed to maintain reasonably good spacing (Woodhead 1934).

Planting. Little need for planting exists in the lodgepole pine type because of the limited area of denuded land and the success with which natural reproduction takes place on cut-over lands. The planting procedure outlined for the Engelmann spruce type can be followed for areas in need of planting. Chiefly ponderosa pine and Douglas-fir transplants should be used.

Slash Disposal

Slash in Relation to Fire

Lodgepole pine produces a relatively large quantity of slash per unit of timber cut, owing to the persistence of dead limbs on the bole almost to the ground. The slash fire hazard decreases rather rapidly, the needles falling in about 2 years, and the finer parts of the slash disintegrating in 3 to 5 years (Thompson 1929) (Fig. 77). Little slash is in evidence after 10 years where utilization is very close.

Cut-over sections covered with lopped slash and given no special fire protection have had no larger proportion of their area burned than cut-over sections on which the slash was piled and burned (Thompson 1929)—strong evidence that slash-covered cut-over lands constitute only a moderate fire hazard.

The size of slash-covered areas affects materially the degree of fire hazard. Scattered, small areas are less hazardous than large, continuous areas.

[1] These spacings are at variance with those given by Woodhead (1934), having been modified since the writing of that article.

Photograph by U. S. Forest Service.

FIG. 77. Five years after lopping, lodgepole pine slash lies close to the ground and is rapidly disintegrating. Lopped slash regulates the density of reproduction, thereby being a distinct silvicultural aid.

Ecological Effects of Slash

As noted previously ("Stand Regeneration and Development," p. 423), slash is believed to be an effective aid in securing correct seedling density (Fig. 77).

Economic Considerations

The cost of complete piling and burning of slash usually is about three times as much as that of lopping. The slash fire hazard is seldom sufficiently high to justify large expenditures for slash disposal.

Application of Methods

For the major part of the lodgepole pine type (note exception below), slash can be disposed of by partial piling and burning combined with lopping. Piling and burning should be the method in the following locations: (1) 100 feet on each side of railroad rights-of-way where fuel oil is not used; (2) 100 feet around camps; (3) 100 feet on each side of main logging roads and highways; (4) 50 feet on each side of trails; and (5) additional strips 100 feet wide (in localities of high risk) to take advantage of all natural fire breaks, leaving no continuous areas of slash exceeding 160 acres. This will involve disposal of 5 to 10 per cent of the slash. The remainder should be lopped. Where roads and trails are likely to erode, they should be covered with lopped slash.

On areas of high fire hazard, chiefly in the northern and western parts of the region, complete piling and burning are recommended.

Special fire protection of slash-covered cut-over land appears unnecessary, except during an occasional dry year of high fire hazard.

Disease and Insect Problems

Although lodgepole pine is attacked by several insects and diseases, the *mountain pine beetle* probably does more damage than all others combined (Mason 1915*a*, 1915*c*). Endemic infestations of the mountain pine beetle characterize all mature lodgepole pine forests. Suddenly, at a certain stage of maturity, an epidemic infestation may develop, ultimately destroying the stand almost completely (Craighead, Miller, Evenden, and Keen 1931). During the endemic stage, chiefly weakened and occasional old trees are attacked. As an epidemic develops, large thick-barked trees are first attacked, but soon all types are infested. The destruction is quite complete in 6 to 8 years, after which the beetles pass on to another area or die out from a lack of food.

Measures to control epidemic infestations of mountain pine beetles are so costly that they must be applied with discretion. Where epidemics are developing, control can be accomplished at a cost low enough to give large returns, in timber saved, on the investment.

The most practical method of controlling the mountain pine beetle appears to be shortening of the rotation for lodgepole pine by thinning (see p. 428). Obviously this does not solve the problem in mature stands, which now really represent the critical problem. For such stands logging offers the most practical solution. By leaving the logs in the woods for 3 or 4 weeks during the beetle's flight, enormous numbers of insects are trapped, thus reducing greatly the insect population of the area (Craighead, Miller, Evenden, and Keen 1931).

Where logging is impractical as a control measure, treatment of individual trees or groups of trees is necessary. Work must be started as soon as there is evidence of the development of an epidemic (when groups of trees are badly affected here and there). To be effective, treatment must be applied to all infested trees on the entire area in a single season, followed by annual maintenance control as long as necessary.

Two defoliators, a *sawfly* and the *lodgepole needle tier,* have done local damage in Yellowstone Park. Working individually they seldom kill a tree, but working together they often do (Burke 1932). These insects are seldom harmful extensively.

In restricted localities the *Black Hills beetle* does damage similar to that of the mountain pine beetle.

Various rots, generally having entered through wounds, occur in all species, but they have not caused extensive loss of merchantable timber.

Mistletoe is present on nearly every tree on poor sites; elsewhere it attacks only an occasional tree. Deformity is the chief result.

Western gall rust attacks lodgepole pine, causing local damage to the bole, but rarely killing a tree.

Control of Animal and Logging Damage

Grazing is of so little consequence in the lodgepole pine type that special precautions are unnecessary.

Under the logging methods now in use lodgepole pine forests are not seriously damaged. Nevertheless, felling and skidding should be under observation in order that excessive damage, if it occurs, can be corrected immediately.

ENGELMANN SPRUCE–ALPINE FIR TYPE

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of Forest

Importance.
  Area—Major.
  Commercial Value—Low, because of inaccessibility.
Sites Occupied—All sites from 9000 to 12,000 feet.
Associated Species.
  Major—Either Engelmann spruce or alpine fir pure or predominant or a mixture of the two predominant.
  Minor—Several of the following: Douglas-fir, grand fir, western white pine, lodgepole pine, whitebark pine, western larch, western hemlock, western redcedar.
Place in Succession—A climax type.

Engelmann spruce–alpine fir forests are chiefly mature, dense, and uneven-aged. Small areas of even-aged forest are similar in size-class structure to the uneven-aged forest, containing trees from sapling to saw-log size. The larger trees in mature stands rarely exceed 30 inches d.b.h. Over extensive areas these forests have average volumes of 15,000 board feet per acre, interspersed with small areas supporting upwards of 50,000 board feet per acre.

A considerable area of denuded land that failed to regenerate naturally after fire exists in the Engelmann spruce–alpine fir zone. The acreage of immature forest and cut-over land is small.

Stand Regeneration and Development. Advance reproduction, chiefly grand and alpine fir, is sparse and irregularly distributed in mature forests. Seed production of the major species appears to be sufficiently frequent and abundant so as not to be a limiting factor in regeneration. Engelmann spruce bears some seed nearly every year and large crops every 3 or 4 years (Hodson and Foster 1910), and the firs are reported to be even more prolific. Seed apparently does not remain viable in the duff after the first germinating season; therefore, reproduction must come from seed produced currently.

Factors controlling Engelmann spruce seedling establishment are imperfectly known. There appears to be a relationship, however, between seedling establishment and thickness of the organic matter and protection of the site from overexposure. Clearcutting in summer was a material aid to spruce seedling establishment on north slopes in

Montana because it broke up the litter and caused it to decompose rapidly, whereas on south slopes clearcutting was inimical to seedling establishment because it overexposed the site (Lowdermilk 1925). In other parts of the region, authorities report that Engelmann spruce reproduction becomes established without the benefit of mineral soil, reproduction being superior on north slopes. The author concludes from this that organic matter does not become so thick because of more rapid decomposition in the more southern latitudes of the region and that the higher soil moisture content on north slopes than on the south slopes favors regeneration on the former sites.

The major species are tolerant; therefore, reproduction of all survives in a dense stand. Likewise, there is so little difference in the rate of growth of the individual species that no one species has a definite advantage over the other in gaining a dominant position in the stand. All species respond readily to release.

Windfall. Windfall is a real problem in cut-over stands, because Engelmann spruce and the firs develop shallow root systems that give the tree poor anchorage. Uncut stands suffer only local damage from windfall because the trees offer mutual support, but cut-over stands undergo extensive injury.

Economic Basis

Economic importance of the Engelmann spruce–alpine fir type is rigidly limited at present by its inaccessibility and the small demand for the timber products that the stand will yield. Extensive utilization is dependent on an enlarged market such as the paper industry might develop.

Growth capacity of these forests is relatively high. Growth in cut-over stands depends on volume of the reserve stand, age of cutting, and species composition (Hornibrook 1942). Mean annual gross increment per acre by the Scribner rule varies from 81 board feet per acre for a period of 60 years after cutting to 364 board feet on a reserve stand of 15,000 board feet per acre for a period of 30 years after cutting.

Application of Methods

Selection Cutting. In those restricted areas on south slopes where they yield products that are reasonably marketable, Engelmann spruce–alpine fir stands, the author believes, may be left in fairly acceptable condition by the selection method of cutting, involving a light cut. Not more than 40 per cent of the merchantable timber over 10 inches d.b.h. should be removed, thus making possible a second cut in about

30 years. Whenever the condition of the stand allows and the market will absorb it, alpine fir should be cut more heavily than the spruce to accomplish maximum stand improvement. Seed trees need not be left since the reserve stand will contain an adequacy of trees large enough to provide ample seed for reproduction.

Stands on north slopes or on sites particularly susceptible to windfall—both cases suggesting the silvicultural need of clearcutting—should not be cut until a market develops for smaller trees than can now be disposed of.

Planting. Planting must be done on the denuded areas. Engelmann spruce is the logical choice for sites originally occupied by the Engelmann spruce-alpine fir type. Four-year transplants, spaced 8 by 8 feet, seem to be the best choice. Spring is the preferred season for planting. The grub hoe is the most effective tool for the rocky, brushy sites that characterize this type.

Slash Disposal

The slash problem in the Engelmann spruce–alpine fir type is much like that of the lodgepole pine type, except that slash does not have the same silvicultural significance. In the Engelmann spruce–alpine fir type it is more likely to be detrimental than beneficial.

The dense spruce and fir crowns produce a large volume of slash. Nevertheless, the slash hazard is not critical (except in the north and west parts of the region), because spruce sites are normally moist, the fire season is short, and the needles drop from the slash quickly—usually during the first year.

Slash disposal costs, for comparable methods, are higher in the Engelmann spruce–alpine fir type than in the lodgepole pine type.

Because of the similarity of conditions in the two types, the system of partial piling and burning, combined with lopping, recommended for the lodgepole pine type (p. 431), is recommended for most of the Engelmann spruce–alpine fir type, exceptions being areas of very low hazard, where lopping is unnecessary, and areas of very high fire hazard, where all slash must be piled and burned.

Disease and Insect Problems

Brown stringy rot commonly occurs in alpine and white fir trees over 12 or 14 inches d.b.h. and spreads rapidly to a height of 8 or 10 feet, thus causing considerable destruction of merchantable material in the larger trees.

The *spruce budworm* occasionally does damage to alpine fir, but its work has never been destructive.

The *Engelmann spruce beetle* reached an epidemic condition in parts of Colorado between 1942 and 1947. An estimated 4 billion board feet of timber was killed.

Concentrating the cut in the alpine fir, as suggested under "Selection Cutting" for the Engelmann spruce–alpine fir type, and particularly cutting it to a low diameter tends to make the forest less susceptible to brown stringy rot and spruce budworm. Control of the Engelmann spruce beetle does not appear feasible.

Control of Animal and Logging Damage

Careful regulation of grazing on the denuded areas is vital, inasmuch as natural regeneration has been slow. Strict regulation of number and distribution of livestock may aid in the establishment of natural reproduction.

Grazing presents no problem in the forest proper, since the stands are too dense to be usable by livestock.

Control of logging damage can be handled in the same manner as in the lodgepole pine type.

INTERIOR DOUGLAS-FIR TYPE

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of Forest

Importance.
  Area—Major.
  Commercial Value—Moderate.
Sites Occupied—Unburned sites, 7500 to 9500 feet altitude, usually small areas on cool, north slopes at lower elevations, and warmer sites at higher altitudes.
Associated Species.
  Major—Douglas-fir is pure or predominant, or a mixture of Douglas-fir and white fir is predominant (Committee on Western Forest Types 1945).
  Minor—In the lodgepole pine region, chiefly ponderosa pine, lodgepole pine, limber pine, Engelmann spruce, bristlecone pine, alpine fir, and blue spruce.
Place in Succession—A climax type.

The virgin forests, constituting a major portion of the Douglas-fir type, are uneven-aged. The stands are of moderate density and the mature trees are small to moderate in size. Ponderosa pine is usually the largest tree. The best virgin stands, situated in the northern part of the region, yield an average of 15,000 board feet per acre over extensive areas with occasional smaller tracts producing 35,000 board feet per acre. The stands of the southern part of the region have average volumes of 5000 to 7000 board feet per acre.

The acreage of selectively cut Douglas-fir forest, immature stands, and denuded areas is small. Areas originally denuded have restocked to lodgepole pine.

Stand Regeneration and Development. Advance reproduction, composed of any species in the overwood but with ponderosa pine and Douglas-fir in the minority, is sparse.

All the important species of the Douglas-fir type are only fair seed producers, but seed is borne with sufficient frequency to provide ample seed for restocking. The maintenance of the proper balance of moisture in the surface soil, which is not easily achieved, is the controlling factor in seedling establishment, particularly for Douglas-fir and Engelmann spruce (Roeser 1929). It seems to be accomplished most effectively by shelterwood cutting, which is followed by a greater number of seedlings of all species combined than is either selection cutting, which rates second, or clearcutting, which rates third in amount of reproduction, both having been applied experimentally in conjunction with shelterwood cutting. In general, white and alpine fir seedlings are less sensitive to sites that are not optimal for regeneration, and, therefore, they usually have an advantage over Engelmann spruce.

The site created by the first cutting of the shelterwood method is reasonably favorable to seedling growth, although not ideal as is a clearcut site. As Douglas-fir reproduction passes into the sapling stage, the balsam firs have an advantage in competition because Douglas-fir is less tolerant than they at this stage.

Fire definitely favors lodgepole pine reproduction, almost to the exclusion of other species.

Windfall. All the more important species of the Douglas-fir type have well-developed root systems. Windfall is not serious even after heavy cutting.

Economic Basis

Except for the occasional Douglas-fir or ponderosa pine tree that produces high-quality lumber, these species, as a general rule, yield

poor lumber. Utilization for railroad ties is more economical. Markets for trees below tie size are very limited.

Small Christmas trees can be marketed profitably in some sections.

Application of Methods

Selection Cutting. Existing markets do not permit the shelterwood method of cutting in mature stands, which, silviculturally, is the best. Selection cutting, which is reasonably successful silviculturally, must be used. It should aim to remove 60 to 70 per cent of the volume of trees over 10 inches d.b.h. Special seed trees are unnecessary, except over small areas where, because the stand is mature or decadent, virtual clearcutting must be applied; in that case, not less than two, and preferably four to six, seed trees per acre should be retained. Douglas-fir and ponderosa pine should be given first choice in the selection of seed trees.

Wherever lodgepole or limber pine, alpine or white fir occur, they should be removed as extensively as economic conditions permit. Defective or poorly formed trees should be cut whenever possible.

Thinning. Where Christmas trees can be marketed, thinnings can be made to advantage in sapling stands. If a stand is to be operated solely for Christmas trees, a heavy thinning removing 70 to 80 per cent of the trees is desirable (Roeser 1928). Much lighter thinnings are advisable where railroad ties are to be the main crop.

Planting. There is little need for planting. Three-year Douglas-fir transplants and the planting technic outlined for the Engelmann spruce type are recommended.

Miscellaneous Silvicultural Problems

The factors affecting slash disposal in the Douglas-fir type are so similar to those in the lodgepole pine type that the same methods are recommended (see p. 431).

Locally, on the Pike National Forest, *pitch girdle* attacks the less thrifty Douglas-fir in dense sapling stands (Roeser 1929). The chief damage is the weakening of the tree, accompanied by reduced growth. Occasional trees die within a few years after the initial attack. Trees in stands of light to medium density are seldom affected.

Properly timed thinnings in sapling stands should prevent attack by pitch girdle (Roeser 1929). This can be accomplished effectively if the saplings can be marketed as Christmas trees. In the absence of

such a market, less intensive thinning aimed primarily at the unthrifty trees should reduce the danger of infection by pitch girdle.

Mistletoe and other fungous diseases attack Douglas-fir and some of its associates, but rarely do they cause extensive damage.

The sanitation features of cutting in mature stands improve the health of the cut-over stands.

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13 · *Southwest Ponderosa Pine Region*

DESCRIPTION AND HISTORY

Location and Landownership

The southwest ponderosa pine region occupies the timbered portions of the state of Arizona, New Mexico, southern Colorado, and southeastern Utah (Fig. 1). The forested areas occur in the mountains of southern Colorado, northern Arizona, and New Mexico, the Colorado Plateau of northern Arizona, and the isolated mountain ranges of the southern part of New Mexico and Arizona.

Most of the land, approximately 25,000,000 acres, is owned by the Federal Government and is administered as national forests. Some timbered land in government ownership is included in the Indian reservations. Privately owned land is largely in the form of small woodlands. There are, however, a few extensive tracts in private ownership, set aside as old Spanish land grants, which have not been absorbed into the national forests. Another class of land, the railroad grants, goes into public ownership as soon as the merchantable timber is removed. Federal ownership of land is, therefore, gradually increasing.

The state of Colorado has small areas of state forests. The states of New Mexico and Arizona own some forest land, not organized as state forests, for which they have cooperative timber sales agreements with the Forest Service.

Physiographic Features

The region is characterized by a variety of topographic conditions. Although some of the region is mountainous, probably the most conspicuous feature is the gently sloping Colorado Plateau of western Arizona, cut through by the canyon of the Colorado River. Rising from the Colorado Plateau are the San Francisco peaks, the highest of which attains a height of 12,611 feet, an increase in altitude of approximately 5000 feet in a distance of 3 to 5 miles. The Colorado Plateau lies

mostly between 4500 and 7000 feet above sea level. On the south, it drops abruptly at the rim into the Verde River valley and Tonto Basin, outside the forested area. It is dotted by numerous volcanic cones that rise to a height of 500 to 1000 feet above the general contour.

Rather rugged mountains reaching 10,000 to 13,000 feet above sea level characterize the rest of the region. The most conspicuous of these mountain ranges are the Sangre de Cristo in northeastern New Mexico, the San Juan Mountains in southern Colorado, and the Santa Catalina Mountains in southern Arizona. Other mountain ranges, too numerous to mention, rise high enough above the desert to support timber.

Deep canyons have been cut into the earth's surface by the numerous streams, which eventually drain in a southwest or southeast direction. Most of the mountain streams are small, many of them uniting to form the large rivers, most of which are outside the timbered areas. The melting of the heavy snow in spring causes high water in the rivers for short periods. The largest and most extensive drainage systems of New Mexico are the Rio Grande and the Pecos River, both flowing into the Gulf of Mexico. The Colorado, the Little Colorado, and the Gila are the chief streams of Arizona.

Nearly every textural class of soil, from the sandiest to the heaviest clay, occurs in the region. The amount of organic matter covering the soil and the nitrogen content of the soil increase with the altitude (Pearson 1931*a*). The most critical soils are those covered by several inches of volcanic cinders, a condition that accentuates the dryness. They occupy an extensive area east of Flagstaff, Arizona.

Climatic Features

Most of the region has a mean annual precipitation between 20 and 25 inches (Weather Bureau 1926). At the high elevations, above 10,000 feet, the precipitation is around 30 inches per year, whereas below 6500 feet it is somewhat less than 20 inches. During normal years, two dry periods occur, one in spring, the other in fall. The spring drought is more acute and longer, except during an occasional year when the fall season may be very critical, the dry weather sometimes extending into December at the lower altitudes. The spring dry season begins about the middle of May, becomes most acute late in June, and terminates with the beginning of the summer rainy season between the first and fifteenth of July. The autumn dry season rarely lasts more than the month of September. Some years it fails to ma-

terialize. July and August are rainy, thunder showers occurring almost daily. Rainfall averages 2 to 3 inches per month at the intermediate altitudes and considerably more at the higher altitudes. Another wet season occurs from December through March, when practically all the precipitation comes in the form of snow. At the lower altitudes snow does not cover the ground continuously in winter, but above 8000 feet it does, often accumulating to a depth of several feet.

The air is comparatively dry the year round, but particularly during the two dry seasons when the relative humidity frequently falls below 30 per cent. Relative humidity is highest during midsummer (July and August), when it frequently rises to 80 per cent or more.

The combination of southern latitude and high altitude prevents extremes in temperature. The summer season is short. On the warmest days, the temperature varies from rarely above 90° F. at 7000 feet to rarely as high as 70° F. at 11,000 feet. The mean maximum temperature for July at Flagstaff, Arizona, elevation 6907 feet, is 80° F. (Weather Bureau 1926). Nights are always cool to cold in summer. The winters are temperately cold, but low temperatures are broken by occasional short periods of mild weather. The mean minimum temperature for January at Flagstaff is 14° F. (Weather Bureau 1926). The summer usually tapers off at the low altitudes into an extended period of bright, moderately dry weather in early autumn.

The average length of the growing season is approximately 4 months, varying from this with change in altitude.

Only one section of the region, the Colorado Plateau in northern Arizona, has an appreciable number of "dry lightning" storms, occurring chiefly in July and August. The Coconino National Forest, situated in the center of this area, had 328 and 518 lightning fires out of a total of 377 and 583 fires during 1936 and 1937, respectively. The occurrence of dry lightning storms in other parts of the region is too infrequent to be of any consequence.

High winds are not common but do occur occasionally. They are most severe at the high elevations, where on exposed situations they do considerable damage. Other than this, they are local and infrequent. The prevailing winds are southwest and west.

Development of Lumbering

The first cutting in this region took place about 1880 in the northern part of the region, on a small scale for local consumption. Much of the early cutting was done for timbers and other products needed

in the development of the gold and silver mines. By 1905, operations had begun in the Sacramento Mountains of New Mexico, and, somewhat later, operations were pretty well scattered over the region at the lower elevations. The most extensive cutting developed in the ponderosa pine type. Localized cuttings were made in some of the high mountains in the vicinity of the mines. The most extensive cutting in the Douglas-fir type developed in the Sacramento Mountains, which, incidentally, support some of the best stands of that type in the region. Because of its inaccessibility cutting of the Engelmann spruce–alpine fir type has been on a very small scale. The largest operation in this type in northwestern New Mexico on the Carson National Forest and adjacent private lands was discontinued in 1926 because of the difficulties and uncertainty of transporting the products out of the region by water.

There was a gradual and sustained increase in lumber production in the southwest ponderosa pine region before the economic depression in 1929. In 1899, the lumber production from Arizona and New Mexico was approximately 67,000,000 board feet; in 1910, 156,000,000 board feet; and in 1925, 298,000,000 board feet (Forest Service 1927). Production is not much in excess of consumption, but competition from other regions diverts the lower grades of material to the eastern and middle-western markets. At the peak of production, it is estimated that between 50,000 and 60,000 acres of forest were cut annually. Since cutting on the national forests is on a sustained-yield basis, the rate of cutting is such that virgin timber will be available until the end of the first cutting cycle, some 20 to 30 years hence.

Large-scale operations have never developed. Portable sawmills operating entirely to supply local needs are numerous. The largest mills, with daily capacities of 100,000 to 200,000 board feet, cutting primarily for the general market, are on the Colorado Plateau of Arizona.

There is probably not a single instance in the region of continuous operation on private lands. Most of the private land was cut at an early date without any policy of sustained-yield operation, and in many cases the land has already been exchanged with the Federal Government for stumpage on the national forests.

The Effect of Past Practices

Most private cut-over lands were left fairly productive because of natural conditions. The uneven-aged forests, containing numerous

trees too small to harvest profitably, were rarely cut to a diameter limit below 10 or 12 inches, thus leaving a fair reserve stand. A low fire hazard kept most cut-over land from burning in spite of the fact that disposal of slash was rarely practiced.

Railroad grants situated in the most accessible parts of the region were cut in about the same manner as privately owned lands.

The original national forest lands were cut conservatively from the start; but many problems, particularly in slash disposal and grazing, in the early years of administration were not solved and limited the effectiveness of management. Consequently, some of the lands suffered from erosion, and tree reproduction was damaged. A considerable area now in national forests was cut under private control before it was acquired by the Federal Government. This land was generally severely overcut and now stands in sharp contrast to the land cut under Forest Service supervision.

In recent years slash disposal and grazing regulations have been more effective, and the results are evident in the form of improved regeneration. All national forest cutting is so planned that the yield will be continuous. Cutting, which removes chiefly the mature and overmature timber, was first established on a 60- to 75-year cutting cycle but is now based on a 20- to 30-year cutting cycle.

Slash disposal on the national forest timber sales has gone through a number of changes, well outlined in a series of articles by several authors (Chapman 1919, Pearson 1921, Pearson and McIntyre 1935, Woolsey 1921). On the first timber sales, the piling and burning method was practiced, but difficulties were encountered in getting the slash burned. To overcome this trouble and to gain certain silvicultural advantages, the lopping and scattering method, later superseded by pulling, was employed. Later, the lopping and scattering method was favored over pulling in some localities. In recent years, both the piling and burning method and the lopping and scattering method have been practiced in accordance with the needs of individual sites. The object now is to gain as much silvicultural advantage as possible through slash disposal without any sacrifice in fire protection.

Relatively little cut-over land urgently needs planting because, under adequate protection, natural reproduction becomes established wherever seed trees are left. Experimental plantings have demonstrated that costs are high, and the best chance for success is at the high altitudes (Pearson 1914). Under the circumstances, and with no urgent need of planting, artificial reforestation is being postponed.

THE FORESTS AND THEIR MANAGEMENT

The forests of the southwest ponderosa pine region are comprised of five distinct types, the interior ponderosa pine, Douglas-fir, Engelmann spruce–alpine fir, and woodland types (two), their commercial importance being in the order in which they are listed, from the most to the least important. The woodland types, however, are the most extensive in area. The forests of this region occupy distinct zones that are demarcated by changes in altitude, even though differences in exposure compensate to some extent for changes in altitude. The woodland types occupy the zone of lowest altitude, followed in order of increase in altitude by the ponderosa pine, Douglas-fir, and Engelmann spruce–alpine fir types.

Virgin forests, with an area of about 13,000,000 acres, predominate. Each of the forest types is discussed in more or less detail in the following pages.

INTERIOR PONDEROSA PINE TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest

Importance.
  Area—Major.
  Commercial Value—High.
Sites Occupied—Relatively dry sites, chiefly at elevations of 7000 to 8000 feet, but extending 500 feet higher on south slopes, and in some localities not extending below 7500 feet.
Associated Species.
  Major—Ponderosa pine (pure over extensive areas).
  Minor—At the lower elevations, various junipers and oaks and pinyon pine; at the higher elevations and on north slopes, Douglas-fir and white fir. On some sites these may be major associates.
Place in Succession—Permanent type.

The virgin stands, the predominant forest condition, are uneven-aged, the different-aged classes occurring as small even-aged groups varying in size from a clump of a few trees to an area of one-quarter acre. Immature saplings and poles are well represented rather generally, giving to the stand a true selection character. Although occa-

sional trees are 600 or more years old, the typical old-growth trees range in age from 200 to 400 years, from 2 to 4 feet in diameter, and 100 feet in height. The quality of the timber is only fair, many of the trees being very limby and containing considerable rot.

The volume of merchantable timber is light, typical stands producing from 6000 to 10,000 board feet per acre, although in some sections, extensive areas produce yields of 20,000 board feet (Fig. 78). A scattered growth of various grasses, annual and perennial herbaceous plants, sage, and other small scrub-like plants, and scrub-timber trees form a low understory in the forest (Pearson 1931*a*).

Photograph by U. S. Forest Service.

FIG. 78. A heavy stand of ponderosa pine on the Sitgreaves National Forest, Arizona. Volume is estimated at 20,000 board feet per acre. A luxuriant growth of grass such as this often interferes with the establishment of seedlings.

The ponderosa pine type has been exploited widely, but virgin forests are still extensive. Selective cutting, applied to a considerable area of national forest, has removed chiefly the least desirable mature and overmature trees, thus leaving the cut-over forest composed mostly of the younger trees and reproduction. A limited acreage of cut-over ponderosa pine type on the railroad land grants supports little else but a few seed trees and seedlings and saplings. Privately owned cut-over lands maintain only seedlings and saplings.

Stand Regeneration and Development. *Advance Reproduction.* In spite of the abundant seed supply in virgin forests—a condition poten-

tially favorable to the establishment of tree seedlings—advance reproduction is seldom adequate (Pearson 1923, Perry 1921) because young seedlings in many instances have been destroyed under a system of overgrazing by livestock [1] (Pearson 1933) or, to less extent, by fire. Because of the long time required, in any circumstances, for an adequate stand of reproduction to become established, preservation of the advance reproduction is vitally important (Krauch 1924). Even with the most effective protection feasible, reproduction on some areas is severely damaged, certain areas fail to reproduce before cutting, and in any case some seedlings are destroyed in logging. Therefore, land needing no additional reproduction after cutting is scarce.

Subsequent Reproduction. Large crops of ponderosa pine seed are produced at intervals of 2 to 5 years. Eight pounds of seed per acre—the amount borne by about four sound, thrifty, large-crowned, well-formed, mature ponderosa pines not less than 21 inches d.b.h.—are needed to produce a full stocking of seedlings. A full stocking can result, however, only when the seed crop coincides with well-distributed precipitation over at least 1 and preferably 2 years (Pearson 1923). Ponderosa pine seed does not germinate until July or August, depending on when the summer rains begin, and so the seedlings are small and poorly developed at the end of the growing season and, therefore, very susceptible to drought and frost heaving.[2]

Some of the soils are not particularly favorable to seedling establishment. Clay soils—unless they contain some organic matter, gravel, and stones—are unfavorable because of their compact structure, which impedes root development and makes them relatively impermeable to moisture and air. Cinder soils represent the opposite extreme in structure and texture. Their surface is so dry that, unless showers occur almost daily, the seed does not germinate. Sandy and gravelly loams are the best soils for seedling establishment. Edaphic and climatic factors—notably soil moisture, air temperature, and light—are so significate in ponderosa pine seedling establishment that the best location is in openings in the forest where other vegetation is sparse (Krauch 1922, Pearson and Marsh 1935).

A herbaceous vegetation that is tall and sufficiently dense to shade most of the ground handicaps pine reproduction by competing for

[1] Grazing on national forests has been greatly reduced in recent years with the result that reproduction has improved.

[2] These and other facts on ponderosa pine regeneration established by Pearson's quantitative studies are corroborated by Perry's observational study in New Mexico (Perry 1921).

moisture and light (Pearson 1934). Arizona fescue (*Festuca arizonica*) is especially detrimental (Fig. 78). It grows during May and June when precipitation is at the minimum and thus reduces moisture in the surface soil to the point at which seedlings cannot survive (Pearson 1942*a*). Mountain muhlenbergia (*Muhlenbergia gracilis*) and

Photograph by U. S. Forest Service.

Fig. 79. The seedlings have become established under controlled sheep grazing following a group-selection cutting in this ponderosa pine stand 13 years previously. Average annual increment since cutting has been 90 board feet.

weeds are less objectionable. After they are 5 or 6 years old, ponderosa pine seedlings have crowns and root systems that are large enough to allow them to compete successfully with the grasses (Pearson 1934). Control of the size of the vegetation (the most practical means is controlled grazing) is one of the essential requirements of pine seedlings (Fig. 79).

Intensive grazing keeps the vegetation down, but during certain stages—especially the second and third years of the seedling's life—it is likely to become excessive and result in severe damage to the tree seedlings. Sheep are the most serious offenders when seedlings are

small, but cattle and horses may injure larger seedlings under poor management. Damaged seedlings have marvelous power of recovery under protection, unless they have been completely defoliated for a few years (Pearson 1931*b*). Retardation of growth is the chief handicap to partially defoliated seedlings.

Field mice, by biting off the tops of seedlings, damage those under 3 years old and girdle large seedlings (Pearson 1934).

Slash may be beneficial or harmful to ponderosa pine seedling establishment, depending on the character of the site (see p. 455).

Stand Development. Normal development of ponderosa pine seedlings occurs in the open where temperature and moisture are nearest the optimum (Pearson 1931*a*). Overhead shade of over 50 per cent has an unfavorable effect on growth and form. Shade from the sides, such as is produced by adjacent large trees, and relatively high light intensity overhead allows normal growth in diameter and height and results in fine branching (Pearson 1940*d*). The shade condition developed in dense sapling groups does not foster fine branching, except possibly in the first few feet of the bole, because the dominants usually attain greater height than the rest of the stand and then develop coarse branches.

Seedlings subjected to severe competition from trees or other vegetation often survive for a decade or more, but their growth is slow and form is stunted. When released such seedlings do not respond well.

Species other than ponderosa pine do not enter into the stand composition in sufficient numbers—over extensive areas, not at all—to have any bearing on stand development.

Growth of the reserve stand depends on the character and spacing of the trees it contains. The general differences in development associated with tree age and vigor which Krauch (1926, 1934) established was studied later in more detail, and a tree classification which contains sixteen tree classes was devised (Thomson 1940).[3] Growth declines by age classes from class 1 to class 4 and by vigor classes from class *A* to class *D*. Defect follows a similar trend (Chapel 1942, Thomson 1941). Decay is generally not critical, however, until trees reach age class 4 or vigor class *D*. The relationship between rate of diameter growth of individual trees and amount of release caused by cutting—growth increases with increased release—established by Krauch (1924)

[3] This is a modification of Keen's classification (see p. 508). It differs from the latter in that class 3 trees have a lower maximum age, 225 instead of 300 years; class 4 trees, therefore, have a lower minimum age; and class *D* is a more inclusive group, since it includes trees with small crowns in any crown class.

and Pearson and Folweiler (1927) has been emphasized more recently, especially in relation to small-crowned trees (Pearson 1943, Wadsworth 1942). Mature trees with small crowns (classes *C* and *D*) make rapid diameter growth—6 inches in 30 years—when they have ample space. Wadsworth concludes that space is more important than crown size or age in rate of diameter growth. Diameter growth varies with size of tree, being faster in trees of small diameter than those of large diameter (Pearson 1938, 1940*c*, 1944*a*). Mortality rises rapidly in trees above 22 to 24 inches d.b.h., and net growth among trees above that size may therefore be negligible (Pearson 1938, 1939, 1940*c*). Furthermore, defect is relatively high in trees of large diameter, especially those over 24 inches (Thomson 1941).

Stand development is sometimes influenced by the Abert squirrel and the porcupine (see p. 458).

Windfall. Windfall in the virgin forest is of limited occurrence except on shallow or rocky soils where root development is restricted. Trees that originally grew in clumps, but are left isolated by cutting, are very susceptible to windthrow.

Economic Basis

Utilization and Marketing Problems. Accessibility and desirable stand composition make the commercial utilization of the ponderosa pine type fit in harmoniously with its silvicultural requirements. The limited market for small-sized products derived from trees under 12 inches d.b.h., however, is an obstacle to profitable thinning. Differential values of species have little practical significance because of the limited occurrence of the low-valued species—chiefly Douglas-fir, white fir, pinyon pine, and junipers—in the stands. The size of the marginal ponderosa pine tree, although not determined by actual study in this region, is probably between 12 and 16 inches d.b.h. A 22-inch ponderosa pine is probably the most profitable silviculturally, but trees of larger diameter yield a higher cash profit.

Growth and Rotation. Growth is slow in the existing understocked stands, net growth generally being under 100 board feet per acre annually (Krauch 1937) (Fig. 79). Lexen (1939*b*) found that the growth of reserve stands was strongly influenced by the volume of the stand and the average diameter of the trees. He found growth to be 257 board feet per acre annually over a 20-year period on a reserve stand of 6000 board feet per acre composed of trees whose average diameter was 12 inches. At the other extreme he found growth of

only 26 board feet per acre annually on a reserve stand of 2000 board feet per acre composed of trees whose average diameter was 32 inches. Obviously growth is also influenced by the classes of trees that compose the stand (see p. 450). Both Lexen and Pearson (1938) suggest that a reserve stand of not less than 4000 board feet per acre is needed to secure a satisfactory sustained yield. The former points out that best results are secured when the reserve stand is composed of trees from 16 to 18 inches d.b.h. Such a reserve stand can make a 20-year cutting cycle possible. Pearson (1944*a*, 1944*b*) found both in Arizona and New Mexico that growth increased for the first 10 years after cutting and gradually declined thereafter (the studies covered a 30-year period after cutting). He believes, therefore, that a cutting cycle of more than 20 years is unwise. Since 140 to 180 years is required to produce a stand in which the trees average 22 inches d.b.h. (the optimal size for profitable production), seven to nine cutting cycles should occur during the rotation.

Financial Aspects. Data on this phase of cutting and planting are meager. Natural reproduction can be secured at small cost if high-risk trees (large, mature trees) are not left for seed (Krauch 1937). With a net increment of 1.71 to 2.79 per cent on the reserve stand (Krauch 1937), seed trees pay their way. Therefore, the chief cost for reproduction (aside from fire protection) is in the reduced revenue that results from regulated grazing, which in no case exceeds 2 cents per acre annually.[4]

Because of the limited markets for material derived from trees too small to yield saw logs and the relatively low income-producing capacity of ponderosa pine stands, it is apparent (although there are no data to substantiate it) that costs for stand improvement must be kept low if the work is to be economically sound. Pearson (1935) believes that an investment of $7.00 per acre for stand improvement will yield an interest of 2 per cent annually plus the return of the capital (Pearson 1935).

Application of Methods

Selection Cutting. Old-growth stands can be managed most effectively by the selection method of cutting (Fig. 79). Cutting should be flexible so that the needs of individual stands can be met (Pearson 1946). Pearson (1942*b*, 1943) recommends "improvement selection

[4] The timber yields a net revenue of $0.30 per acre annually (Pearson 1927).

cutting," the objectives of which he describes as follows: "Improvement selection cutting aims to coordinate silvicultural and economic objectives in such a way as to realize maximum increment and maximum values while building up a growing stock capable of yields in volume and quality commensurate with the productive capacity of the site. In general, merchantable trees which have attained the peak of value increment are harvested; those which still have high potentialities are reserved as growing stock; and minus-value trees are eliminated in the cheapest way possible." [Permission of the Society of American Foresters to use this quotation from the *Journal of Forestry* is acknowledged.] He advocates a 10-year cutting cycle.

Improvement selection cutting differs from maturity selection cutting (see p. 514) in that it removes worthless trees (at some expense), and it lacks a factual basis for evaluating the economic value of individual trees. Critics of this method (see Pearson 1942*b*) contend that it overemphasizes silvicultural improvement at too great a cost. Pearson (1943) advises looking first at the bole of trees, then at spacing, and lastly at the crown in choosing trees to be retained in the reserve stand.

Cutting should concentrate on the overmature and mature trees (age classes 3 and 4) over 22 inches d.b.h., leaving enough of the latter, however, to provide an adequate seed source, and when these trees are thrifty, to maintain an adequate volume in the reserve stand (Pearson 1938, 1940*c*, 1944*b*). Small-crowned trees, if their crowns show no signs of physiological decline, should be retained in the reserve stand, but they must be released (Wadsworth 1942). Cutting of the larger merchantable trees in immature groups is essential to maintaining satisfactory growth among the younger trees.

Where advance reproduction is inadequate or is under 2 feet in height, seed trees must be left (in the latter case, for insurance)—four per acre if there is no established reproduction, and correspondingly fewer as the amount of large reproduction increases. They should be sound, thrifty, large-crowned, well-formed ponderosa pines between 20 and 25 inches d.b.h. (Pearson and Marsh 1935). In northern New Mexico and some other sections trees as small as 18 inches d.b.h. are regarded as acceptable, because reproduction becomes established more readily than in northern Arizona.

On wind-swept sites, exposed slopes, and cinder soils, where the stand of saplings and poles does not give adequate site protection, occasional mature trees should be retained.

Defective trees should be cut on the basis of the severity of the defect and the number of defective trees present. Since mistletoe cannot be completely eradicated, mistletoe-infected trees should be cut discriminatingly (see p. 457). Severely infected old trees should be cut unless their removal will result in undue exposure of the site or jeopardize the establishment of an adequate stand of reproduction.

Cultural Operations. In the group-selection type of forest, characteristic of the ponderosa pine forests, there are both understocked and overstocked immature tree groups that need treatment if the stands are to be as productive as possible of high-quality products. Thinning and other forms of stand improvement are necessary in these stands. This work can be done most advantageously when the commercial timber is cut. It should probably be confined to stands on good sites, accessible to market, and capable of responding to treatment (Pearson 1940*a*). Although thinning technic has not been well developed, it is generally recommended that thinning be confined to the release of not more than 120 crop trees per acre with no two trees closer together than 15 feet. In understocked stands where natural pruning is unsatisfactory, pruning of eighty trees per acre may be advisable (Pearson 1936). Pruning is a means also of preventing the entrance of western red rot into the boles of young trees (Andrews and Gill 1943). Where trees over 6 inches d.b.h. need to be disposed of, poisoning with sodium arsenite is the most economical means (Lexen 1939*a*, Pearson 1937).[5]

Planting. Planting is too costly to justify its widespread use, but it may have application under such special conditions as: (1) supplementing natural reproduction and (2) re-establishing the forest on denuded areas of high value, as when high recreational or watershed values supplement timber value. To keep down cost, spacing of 15 by 15 feet is recommended in planting (Pearson 1940*b*). Use of 1½-1 or 2-1 ponderosa pine stock is recommended. Planting in April is preferable to fall planting, but if soil moisture conditions are good—ample moisture to a depth of at least 1 foot—planting in October or November is not objectionable. Vegetation should be removed before planting for a distance of 2 to 3 feet around the tree.

Direct seeding may be more economical than planting on stony soils (Pearson 1940*a*). Sowing 15 to 20 seeds per seed spot and protecting the spots with wire screens is recommended.

[5] Good results have been secured by applying sodium arsenite in holes ¾ inch in diameter and 5 inches long, bored into the tree 2½ feet above ground. Trees dying from such treatment have not been attacked by *Ips* beetles (Lexen 1939*a*).

Slash Disposal

Slash in Relation to Fire

Slash resulting from the cutting of old-growth forests contributes greatly to the fire hazard of cut-over land. Although the condition in which slash is left—whether lopped, lopped and scattered, pulled, or left in place—does not influence markedly the severity of the fire hazard, it does influence the duration of the hazard, unlopped slash being risky only about one-half as long as lopped slash (Long 1915). As long as the needles are attached to the twigs—2 to 3 years—the hazard is high. When they fall, the danger drops abruptly; but thereafter its diminution is slow. After 8 to 10 years the hazard is low, but it is not gone completely for about 15 years.

Ecological Effects of Slash

The ecological effect of slash is variable, depending on the character of the site with particular reference to the presence or absence of herbaceous vegetation. On soils bare of vegetation, slash, by conserving moisture and reducing soil temperature, is beneficial to ponderosa pine seedlings.[6] Under intensive grazing, the slash protects the seedlings against browsing. On sites that support a dense cover of herbaceous vegetation, particularly Arizona fescue, slash is likely to be detrimental to regeneration, because its presence stimulates the growth of vegetation at the expense of the young tree seedlings (Pearson 1934).

Economic Considerations

The cost of slash disposal varies with the method of disposal, the character of the stand, type of labor, and other factors (Pearson and McIntyre 1935). Based on the average cost of complete piling and burning, which required about 2 man-hours per thousand board feet of timber cut, other methods have the following relative costs: pulling, one-fourth to one-half as much; lopping and scattering, one-half; diversified slash disposal, one-half to nearly as much (average two-thirds). Seldom are timber values or the fire hazard sufficiently high to justify complete burning. Nice judgment is necessary to effect a proper compromise between cost and optimal effect on fire hazard and silviculture.

[6] Unless it is so dense (which it seldom is) as to interfere mechanically with the establishment of seedlings.

Application of Methods

Diversification of method should be the underlying principle in slash disposal (Pearson and McIntyre 1935). The local fire hazard, forest values, and the site itself should determine the method best suited to a particular piece of cut-over land. In general, a combination of partial piling and burning with lopping is recommended for widest use, but there are places where pulling or no treatment can be employed.

Complete piling and burning are recommended under the following conditions: (1) where the fire hazard is very great; (2) where forest values are high; (3) where the slash will be harmful to reproduction, e.g., sites supporting a dense cover of Arizona fescue.

Lopping and scattering, in conjunction with piling and burning, should be employed only where such treatment will aid in controlling soil erosion.

Pulling or leaving the slash as it falls, except on firebreaks, is permissible in very open stands lacking reproduction.

Under a system of partial piling and burning, the amount of slash that must be so treated is determined chiefly by the degree of fire hazard. The piling and burning should be done on firebreaks 100 to 200 feet wide surrounding areas of about 160 acres—more if the fire hazard is high, less if the fire hazard is relatively low. Special fire protection should be in effect on such areas for 10 or more years.

Disease and Insect Problems

Ecological Basis

Western red rot is the chief cause of defect in ponderosa pine. This rot commonly reduces the merchantable volume of old-growth stands by 10 to 15 per cent, and, over limited areas, by as much as 30 per cent. Although most damaging in mature and overmature trees, the rot is present in many immature trees, having entered through dead branches which, in open stands, persist for many years (Long 1917). The incidence of western red rot in young stands was found to increase as stand density decreased (Andrews and Gill 1943).

Mistletoe is widely distributed on ponderosa pine. Although attacking trees of any age, immature trees are more susceptible to infection and are more likely to be severely injured than mature trees. It is most damaging on poor sites where nearly every tree is infected. Mistletoe retards growth and kills numerous trees.

Several species of *bark beetles* are more or less common. Seldom do they cause epidemics, but occasionally in association with pine beetles of the genus *Ips* they destroy numerous trees (as on the Prescott National Forest in southern Arizona in 1928 and 1929) (Pearson and Marsh 1935).

The *southwestern pine beetle,* the most prevalent of the bark beetles in this area, has a decided preference for overmature trees (Craighead, Miller, Evenden, and Keen 1931).

Ips beetles attack mainly young trees in the sapling and pole stages. They are most likely to cause damage accompanying or following prolonged droughts, and in the vicinity of freshly cut slash when cutting is suspended (Division of Forest Insect Investigations 1927).

Two species of *tip moth* are prevalent on ponderosa pine seedlings and saplings in areas near the lower border of the pine zone. Reduced growth and deformity are the main forms of damage.

Control Methods

The control of western red rot is dependent on the removal of most of the severely infected trees from old-growth stands in selection cutting, the development of fully stocked stands of reproduction, pruning of crop trees, and the treatment of material—the unutilized tops and logs—on which the fungus produced fruiting bodies.[7]

Because of the uncertainty of the extent to which mistletoe can be controlled at a justifiable cost, what should be done to try to control it is questionable. For infected trees of merchantable or near-merchantable size, pruning has been suggested, not so much as a control measure as to improve the quality of the tree (Perry 1922), but the value of this practice is debatable. Until more is known about the control of mistletoe, it is probably best to limit the effort to the removal, in selection cutting and thinning, of badly infected trees.

In general, control of bark beetles should be regarded as a part of the silvicultural operations, the objective in all cutting being to remove trees that are susceptible to insect attack. In addition, if at any time cutting operations are suspended in localities subject to *Ips* attacks, all slash should be burned and the bark should be peeled from large material left in the woods after logging. When bark beetles become epidemic, infested trees must be felled, the bark removed from them,

[7] This can be done most effectively by peeling the bark from all logs or limbs over 6 inches in diameter, charring them in slash burning, or keeping them off the ground.

and, if the southwestern pine beetle is involved, the bark should be burned.

Control of Animal and Logging Damage

Because of the damage that can be done to ponderosa pine seedlings by improper grazing practice, rigid control of livestock is essential. Grazing should be regarded as a silvicultural measure, rather than as the utilization of a forage crop (Pearson and Marsh 1935). Proper management on the range, such as salting, maintenance of the correct numbers and distribution of animals, and the selection of the proper class of animals must be applied to all lands uncut as well as cut-over forests. On areas supporting a heavy stand of Arizona fescue and little reproduction, grazing should be fairly heavy until a good seed crop germinates,[8] and it should then be restricted to avoid seedling damage (poisoning of rodents at this stage is recommended). During the first and second seasons grazing must be carefully regulated, because at that period seedlings may be killed by the biting off of the entire crown; thereafter, browsing is less likely to be fatal but must nevertheless be kept under control (Pearson 1934). A careful check should be kept on cut-over lands particularly, in order that adequate regulatory measures may be instituted if reproduction is being damaged. If more than 5 per cent of the reproduction on 10 per cent (or a comparable combination) of the area is being injured, special control measures must be applied. Keeping stock off the range until about the middle of July, or until the new shoots mature, will practically prevent browsing of the tree seedlings' leaders. Complete exclusion of the class of stock concerned until the seedlings are 2 years old, and seasonal exclusion thereafter, is necessary where young seedlings are being killed in excessive numbers. Only by close observation is it possible to secure the maximum benefits from grazing.

Where porcupines are actively doing damage—they girdle the leaders of young trees, thus causing subsequent stagheadedness—their numbers must be reduced by poisoning with a strychnine and salt bait (Gabrielson and Horn 1930).

The Abert squirrel, although sometimes doing serious damage to occasional trees by cutting off small twigs—in severe cases causing complete defoliation—is not serious enough to require artificial control.

Where tractors are used in logging, unnecessary damage can be avoided by laying out routes of travel in advance, instructing the

[8] Heavy grazing—if not so heavy as to destroy all ground cover—not only prepares the seed bed but also discourages the propagation of mice.

timber fallers to fell trees into openings, or, if there are no openings, away from spots where serious damage might be done, instructing swampers not to cut young growth, and insisting that tractor drivers keep on the roads as far as practicable (Wales 1929).

Where steam skidders are used, the following precautions must be observed: (1) Use ground lines only, run at right angles to the railroad track. (2) Skid trails must be parallel to each other. (3) Logs should be skidded into the trails by horses. (4) Exercise the utmost care in all operations to avoid damage to young growth (Pearson and Marsh 1935).

INTERIOR DOUGLAS-FIR TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest

Importance.
- Area—Extensive but secondary.
- Commercial Value—Moderate.

Sites Occupied—Moderately moist cool sites between 8000 and 9500 feet.

Associated Species.
- Major—Douglas-fir (occasionally pure over small areas); at lower elevations, ponderosa pine, white fir, limber pine; at higher elevations, Engelmann spruce, white fir, corkbar fir.
- Minor—Blue spruce, aspen. The aspen usually occurs in patches.

Place in Succession—Probably permanent type.

The virgin Douglas-fir forest, the predominant type of forest, is uneven-aged, containing a generous quantity of saplings and poles. Douglas-fir and white fir are the largest trees, many of them 3 to 4 feet in diameter and 100 feet in height. Ponderosa pine, although not numerous, attains large size and excellent form. Virgin stands produce 6000 to 10,000 board feet per acre over most of the region, except in the Sacramento and Graham Mountains in the southern part of the region, where individual acres yield 40,000 to 50,000 board feet and extensive areas produce an average of 20,000 board feet per acre (Pearson 1931*a*).

Cut-over stands, constituting a relatively small acreage, are uneven-aged, but they contain no overmature trees and fewer mature trees than the virgin forests.

Extensive areas originally occupied by the Douglas-fir type but devastated by fire before fire protection was organized are now occu-

pied by aspen, but they are slowly developing an understory of Douglas-fir that has seeded in from scattered islands of seed trees (Fig. 80).

Stand Regeneration and Development. The amount of advance reproduction in old-growth forests varies greatly. Some stands support little or none, others are nearly fully stocked, and still others

Photograph by U. S. Forest Service.

FIG. 80. Where extensive areas of the Douglas-fir type have been burned, aspen takes temporary possession of the site; but these areas slowly restock to Douglas-fir from the seed disseminated by trees scattered over the area. This area was burned 35 years ago.

support an intermediate amount. An abundance of saplings and poles in some stands makes a reproduction stand of little or no immediate importance.

The needs of Douglas-fir reproduction are imperfectly known, but it has been determined that an abundant source of seed is indispensable because rodents, notably mice and spruce squirrels, sometimes destroy a large proportion of the seed (Krauch 1936). On a study area in the Sacramento Mountains in southern New Mexico, control of rodents resulted in an increase of 182 to 336 per cent in the regeneration of Douglas-fir (Krauch 1945). Associated species also showed large increases in regeneration when rodents were controlled.

Soil moisture is regarded as the dominant physical factor in Douglas-fir seedling establishment, although on some sites heat, light, and

atmospheric humidity are very important also. A mineral soil overlain by an inch or two of well-decayed organic matter, a condition difficult to secure and regulate, is the ideal seed bed for the establishment of Douglas-fir seedlings because of the favorable moisture conditions.

Cutting of a stand should, theoretically, improve soil moisture conditions and undoubtedly does increase the total moisture supply; but the exposure accelerates evaporation. Thus, the upper inch or two of the soil is actually drier after than before cutting, a condition that is distinctly unfavorable to the establishment of new seedlings. Therefore, only during a season of more than average rainfall will the site under any type of cutting be favorable to Douglas-fir seedling establishment. On the other hand, established seedlings with well-developed roots find an improved environment in the greater moisture supply in the deeper soil layers (Pearson and Marsh 1935).

Differences in amount of tree canopy have more influence on the regeneration of the associated species than on Douglas-fir. On cool sites, a dense or moderately dense canopy favors the regeneration of alpine fir, blue spruce, white fir, and Engelmann spruce, to the exclusion of Douglas-fir. On relatively warm sites, an open canopy favors ponderosa pine or limber pine, a moderate canopy favors Douglas-fir.

Cutting that encourages the development of a heavy herbaceous cover is undesirable because the vegetation offers severe competition to tree seedlings—more than do shrubs or trees (Krauch 1936). Douglas-fir and the balsam firs offer more competition to seedlings than do pines, oaks, or aspen; in fact, there is much evidence to indicate that Douglas-fir reproduction is favored by a cover of the latter species.

Once established, fir and spruce seedlings have an advantage where competition is intense. Where competition is moderate, Douglas-fir can hold its own because of its superior rate of growth. Ponderosa pine seedlings must have an open site if they are to survive.

Windfall. Windfall seldom occurs except where heavy cutting has left trees exposed. The spruces are the most susceptible; other species have very low susceptibility.

Economic Basis

Information on the economic aspects of the silviculture of the Douglas-fir type is woefully inadequate; as a matter of fact, there are practically no concrete data.

Ponderosa pine and Douglas-fir are the most valuable species. White fir, owing chiefly to prejudice on the part of the wood users, is

marketed with difficulty. As in the case of the ponderosa pine type, there is little demand for small material. In some sections there is a strong market for ponderosa pine and Douglas-fir cross-ties, and in such places cross-tie utilization is more profitable than saw-log utilization.

Meager data indicate that growth of the Douglas-fir type is about the same as that of the ponderosa pine type. Therefore, the same rotation (150 to 200 years) and the same cutting cycle (20 to 30 years) appear feasible.

Photograph by U. S. Forest Service.

FIG. 81. Selection cutting in the interior Douglas-fir type which left a reserve stand of 5122 board feet per acre (19.1 per cent of the original stand). Growth during the 10-year period immediately following cutting was 132 board feet per acre annually.

APPLICATION OF METHODS

In general, selection cutting is recommended for old-growth stands of the Douglas-fir type (Fig. 81), although certain facts suggest that seed-tree cutting, or at least heavy cutting of some kind followed by broadcast burning of slash,[9] may be better for dense stands with little or no reproduction (Krauch 1936). Where seedlings, saplings, and

[9] The purpose of the broadcast burn would be to encourage a nurse cover of aspen or oak. The objections to this practice are the serious difficulty in controlling the fire and the impossibility of conserving whatever young growth there is on the area.

poles are abundant, selection cutting is undoubtedly the most desirable method (Fig. 81).

In the absence of reproduction, Douglas-fir seed trees, not less than 16 inches d.b.h., and preferably 18 inches d.b.h., must be left at a rate of six per acre. Ponderosa pine may be left as a source of seed, especially on the warmer sites or adjacent to large openings in the stand.

Improvement of stand composition should be one of the objectives of cutting. This implies the removal of white fir and limber pine to as low diameters as is economically feasible.

There has been insufficient experience in the treatment of young stands to justify a discussion of methods.

Planting should soon occupy a limited place in the silviculture of the Douglas-fir type on areas that have high value for recreation or watershed protection as well as for timber.

Slash Disposal

Differences in the slash fire hazard of the Douglas-fir and ponderosa pine types are of minor consequence. If anything, the hazard of the former is somewhat lower because the site it occupies is a little more moist.

In exposed situations, slash, because of its protective influence, may be of appreciable value to reproduction. On cold, shaded slopes, slash, because it obstructs sunlight, is detrimental to the establishment of seedlings.

Slash-disposal costs are about the same as in the ponderosa pine type.

In view of the foregoing, the method of partial piling and burning of slash, as outlined in the plan for the ponderosa pine type (see p. 456), is recommended.

Disease and Insect Problems

Brown stringy rot is common in the trunk of white firs over 12 inches d.b.h., where it does extensive damage to the butt log. The larger mature trees have little commercial value.

Red ring rot infects mature Douglas-fir trees, but the percentage of defect from this cause is not high.

The *spruce budworm,* according to evidence by Perry, defoliates white fir periodically (Perry 1922). It may be a beneficial "pest" by preventing an increase in the proportion of white fir in the Douglas-fir type.

The *hemlock looper* has been found on the balsam firs in the Sacramento Mountains, completely defoliating both old and young trees. Fortunately the damage has not been extensive.

Neither diseases nor insects are sufficiently damaging to require special control measures. Judicious removal of defective trees in all cutting operations and a rotation of 80 to 100 years for white fir should keep the rots in check. Cutting of the balsam firs to low diameters automatically effects some control over the hemlock looper and spruce budworm.

Control of Animal Damage

Since grazing does not often interfere with regeneration—the Douglas-fir type is generally used strictly for summer grazing—special regulation of livestock is unnecessary. Good range management is essential, however, and, in the event of any damage to tree seedlings, corrective measures must be applied at once.

ENGELMANN SPRUCE–ALPINE FIR TYPE

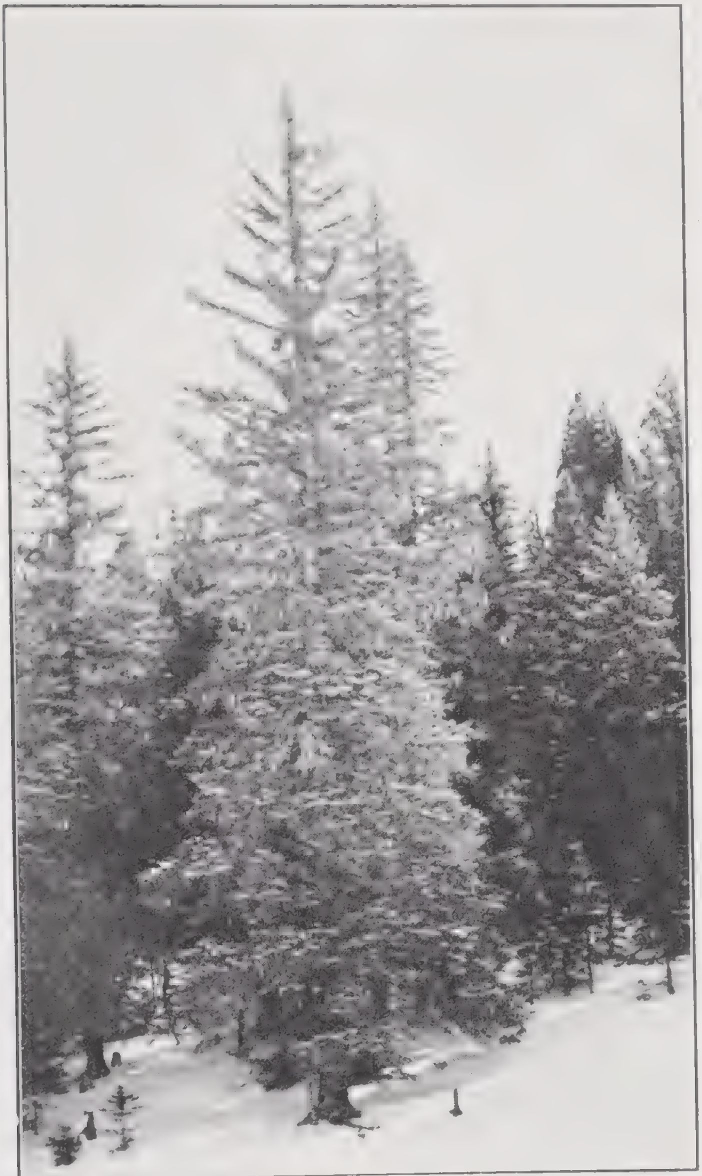
Cutting and Planting

Ecological Basis

Composition and Character of Forest

- Importance.
  - Area—Secondary.
  - Commercial Value—Potentially high, but at present low owing to inaccessibility.
- Sites Occupied—North slopes and other cool aspects from 9500 to 11,500 feet.
- Associated Species.
  - Major—Engelmann spruce, corkbark fir, alpine fir.
  - Minor—Douglas-fir at lower elevations; bristlecone pine and limber pine on south slopes.
- Place in Succession—Climax type.

The old-growth Engelmann spruce–alpine fir type is even-aged, but it has more the form of an uneven-aged stand because of the wide variation in individual tree size caused by the dense stocking. Few trees in such stands are over 18 inches d.b.h., but occasional trees 30 inches or more do occur in openings. The continuity of the forest cover is broken by numerous grass parks of several acres (Fig. 82).



Photograph by U. S. Forest Service.

FIG. 82. Virgin Engelmann spruce–alpine fir stands are usually dense, but the forest cover is broken by "parks." Advance reproduction often becomes established in openings.

Average stands range in volume from 8000 to 15,000 board feet per acre, but the best sites support 40,000 board feet per acre over small areas (Pearson 1931*a*).

The dense stands support little vegetation other than mosses and lichens. Leaf litter is from 1 to 3 inches deep.

The virgin forest is the dominant form of Engelmann spruce–alpine fir stand. Cut-over lands ordinarily support a fairly good reserve stand immediately after cutting, but they have suffered severe windthrow soon after cutting with the result that the older cut-over lands are not well stocked with the larger trees.

Extensive areas formerly occupied by this type were denuded by fires between 1880 and 1890. These burns became occupied by aspen soon after; later, spruce and fir became established on many areas so that they are now occupied by two-storied forests.

Stand Regeneration and Development. Advance reproduction, in which the firs (corkbark and/or alpine) predominate, is abundant in many stands. In these stands the reproduction problem is solved to a large extent. Where advance reproduction is deficient real difficulties are encountered, because both Engelmann spruce and the firs, especially the former, are sensitive to moisture and temperature. Spruce seedlings are very sensitive to the drying of the surface layers of the soil during and for several months after germination (Pearson and Marsh 1935). On cold sites (either in dense forests or at high altitudes) low temperature seems to be a limiting factor in regeneration. Seedlings start, but their growth is poor. The firs reproduce more readily than the spruce on nearly all sites. In general, a partial canopy leaves the site most favorable for regeneration.

The advantage that any species has is due not to marked differences in growth or tolerance but to differences in ability to become established. The firs thereby have an advantage.

Windfall. Owing to shallow rooting of the major species, the wet condition of the soil at certain seasons, and occasional high winds, windfall is a real threat. The hazard is greatest on cut-over lands. In one case in northern New Mexico, the net annual loss from windfall during the first 5 years after cutting was 174 board feet in a reserve stand of 2500 board feet.

Economic Basis

Inaccessibility and a market only for trees that will yield saw logs or cross-ties, are unfavorable factors in the utilization of the Engelmann spruce–alpine fir type. This situation has dictated a method of

cutting that is silviculturally undesirable. Adequate utilization must wait upon a market for small trees, such as would be possible if pulpwood were in demand. Engelmann spruce is superior to any of its associates for any product for which it might be used.

Theoretically, the Engelmann spruce–alpine fir type should produce as much increment as the ponderosa or Douglas-fir types. Actually, however, on lands cut over by a method that cannot be classed as silviculturally desirable, there is a loss in volume, owing to severe windthrow, during the first 5-year period after cutting. A rotation of 120 to 140 years and a cutting cycle of 30 to 40 years is feasible under proper utilization and silviculture.

Application of Methods

In view of the inadequate markets for the class of material (small trees) that would make possible cutting that is silviculturally desirable, the uncertainty of profitable management under existing market conditions, and the high value of these forests for watershed protection, deferring of cutting until such a time that intensive silviculture can be practiced is recommended for the major part of the Engelmann spruce–alpine fir type.

Wherever local conditions are such that the silvicultural requirements can be met reasonably well, shelterwood cutting [10] is recommended for the warm sites (south, west, and east slopes) and clearcutting of small areas is recommended for cold sites (north slopes).

Treatment of young stands is not feasible at present.

Slash Disposal

Although, potentially, the slash resulting from the cutting of old-growth forests constitutes a high fire hazard for a long period—at least 15 years—the generally moist condition of the site keeps the hazard low, except during drought years and for a very short period in late spring and early fall.

Slash is likely to have a detrimental effect on the establishment of tree seedlings on cold sites, because it lowers the temperature. On warm sites its effect is probably neutral.

The method of partial piling and burning of slash as outlined for the Engelmann spruce–alpine fir type of the lodgepole pine region (p. 435) is recommended.

[10] Light selection cutting undoubtedly has merit also.

Disease and Insect Problems

Brown stringy rot in the firs and *western red rot* in Engelmann spruce are the chief causes of defect. Damage is most severe in the firs, the older trees often being badly decayed to a height of 15 or more feet. Control is dependent on judicious cutting practices.

The *spruce budworm* is found from time to time on the firs. Severe outbreaks have not been recorded since the national forests have been in existence. It is wise to keep the Engelmann spruce–alpine fir forests under close observation so that, in the event of a serious outbreak, control can be initiated at once.

Control of Animal Damage

Additional study of the "spruce barrens," the cause of which has been attributed to overgrazing by sheep (Loveridge 1924), is needed as a basis for an intelligent solution of this problem. It may be that lighter grazing is needed if these areas are to reproduce naturally.

WOODLAND TYPES

The woodland forests, represented by two distinct forest types, the pinyon-juniper and western white oak (Pearson 1931*a*), are valuable chiefly as local sources of fence posts and fuelwood, as a range for early and late grazing, and for watershed protection. The pinyon nut crop is an important source of cash income—estimated at $700,000 in Arizona and New Mexico in 1936—from the pinyon-juniper type. The woodland types occupy the lowest altitudinal zone at which trees will grow, namely, 4500 to 7000 feet. The pinyon-juniper type is the most valuable because of the dominance of the more desirable commercial species, pinyon pine, Utah juniper, and one-seed juniper. A good description of the pinyon-juniper forests and appraisal of their value and future is given by Howell (1941).

The value of their commercial wood products in monetary terms is relatively low since the stands are open, growth is slow (170 years being required to produce commercial products) (Chapman and Behre 1918), and they yield only the lower-valued products—fence posts, fuelwood, and cross-ties—yet their accessible location and special values make these forests important in the local economy.

Virgin and cut-over forests, alike, are open, and it is doubtful whether their stocking can be improved materially under forest management, because the climate of the site is very severe. Sheep apparently have played a part in the extension of the junipers into adjacent grasslands (Miller 1921). Little is known about the reproduction and growth requirements of these forests.

It is apparent that conservative management is essential to the maintenance of the delicate balance of conditions in the woodland types. Selection cutting should remove not more than 50 to 60 per cent of the volume over 6 inches d.b.h. Stand improvement, through the removal of defective and poorly formed trees, should be the goal.

Because the slash is valuable for site protection and is so light that it creates little fire hazard, it should be left untreated. There is some evidence that slash may also aid in seedling establishment (Meagher 1943).

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14 · *California Pine Region*

DESCRIPTION AND HISTORY

Location and Landownership

The California pine region includes most of the timbered land of California, exclusive of the redwood region. It includes both the east and west slopes of the Sierra Nevada, the plateaus of northeast California, and the valleys and seaward slopes of the Coast Ranges with the exception already noted (Fig. 1).

Fully 75 per cent of the region is timbered. The total area of commercial forest is 13,680,200 acres. National forests constitute 56.6 per cent, privately owned forest 43.0 per cent, and state or municipal forests 0.4 per cent of the forest-land area. The national forest land in the upper Sierra Nevada and the Coast Ranges is in a fairly solid block; in the lower mountains it is somewhat broken by small blocks of private lands. The acreage of land in national forests is being increased by the acquisition of privately owned cut-over land in exchange for stumpage. Of the 6,500,000 acres of forest land in private ownership, only about 2,000,000 acres are in large consolidated tracts of 50,000 acres or more. One lumber company owns 600,000 acres fairly well consolidated, and one railroad company owns approximately 1,250,000 acres checkerboarded by holdings in other ownership. The remainder of the private holdings are in small blocks (Fritz 1930).

Physiographic Features

The California pine region is characterized by a variety of physiographic features. The Modoc Plateau, a small area in north-central California, bounded on the east by the Warner Mountains and on the west by the Cascade Mountains, is chiefly of volcanic origin.

The most extensive feature of the region is the Sierra Nevada, which has its origin just north of the North Fork of the Feather River. Its crest is highest at the southern end. The east slopes are abrupt, the gradient being as great as 1000 feet per mile in some sections. In contrast, the west slopes have an average gradient of only 100 feet per mile. The west slope has a washboard appearance from south to north, owing to the numerous valleys that cut into the mountains almost at right angles to the crest of the range. Much of the topography is fairly steep, the slopes rising abruptly from the water courses but flattening into rather extensive benches at somewhat higher elevations. Above these benches are moderate slopes at an altitude of 6000 to 8000 feet. The foothills of the Sierras terminate rather abruptly in the very level Valley of California at an altitude of approximately 5000 feet.

The California Coast Ranges and southern extent of the Klamath Mountains form the western section of the California pine region. The Coast Ranges, a series of low mountains running nearly parallel to each other in a northwest-southeast direction, are characterized by rounded ridges. Most of the Coast Ranges lie between 2000 and 4000 feet, with a few peaks above 5000 feet.

The Cascade Range, joining the Sierra Nevada on the north, has numerous high peaks. The topography is rough, the slopes steep, and the surface dissected by numerous streams.

Much of the water drainage is by way of the Sacramento and San Joaquin Rivers into San Francisco Bay. Both rivers, fed by numerous tributaries, have gentle gradients and sluggish currents. The largest tributaries of the Sacramento River are the Pitt, Feather, Yuba, and American Rivers. The most important tributaries of the San Joaquin River are the Merced, Toulomne, and Stanislaus Rivers. The northwest portion is drained by the Klamath, Eel, and smaller rivers, which flow directly into the Pacific Ocean.

There is a large number of small mountain lakes at the high altitudes. The largest is Lake Tahoe, which lies partly in California and partly in Nevada.

The soils vary greatly, some being residual, others having been glaciated, and still others being of volcanic origin. The soils of the lower mountains are chiefly residual sandy loams and loams, derived from a variety of parent materials. The soils of the Sierra Nevada above 5500 feet on north slopes and above 6500 feet on south slopes have been glaciated. These soils abound in rocks. Volcanic pumice soils are characteristic of the Modoc Plateau.

Climatic Features

The climate of the California pine region has marked local differences, caused by the wide latitudinal range, the striking relief, and the relation of the prevailing winds to the outstanding topographic features.

Average annual precipitation varies from somewhat less than 20 inches at the lower altitudes of tree growth to more than 75 inches in the northern Sierra Nevada and the Coast Ranges (Weather Bureau 1926). The south, southwest, and west faces of the mountains are rainy, whereas the north, northeast, and east faces are relatively dry. The zone of maximum precipitation is at approximately 5000 feet in the central Sierra Nevada. The heaviest average annual precipitation in the northern Sierra Nevada is approximately 75 inches; in the southern two-thirds of the Sierras it is only 40 inches.

The precipitation is seasonal, being very light during the midsummer months and heavy in winter. July and August are especially dry, rain sometimes failing to materialize during this period in dry years. Beginning in September, the precipitation gradually increases. The heaviest fall, mostly in the form of snow, occurs from December to late March, after which there is a gradual diminution. The fall of snow is heavy in the high mountains, some sections recording between 300 and 400 inches annually. In the drier sections the average annual snowfall is from 75 inches up.

Low relative humidity is characteristic, especially during the summer months. The relative humidity frequently falls below 30, and occasionally it descends below 20 per cent during the driest part of the day. Such low humidity may be followed by a rise to 70 per cent during the night.

The diurnal range in temperature is wide, particularly at the middle altitudes. Temperatures of 80° and 90° and sometimes 100° F. are followed by cool nights. Extended periods of hot weather seldom occur. The winter is moderately cold, the temperature occasionally falling below zero. Short periods of mild weather occur during winter. At the lower altitudes, the snow may disappear completely.

The growing season is fairly long at the lower altitudes and short at the high altitudes. It varies from approximately 6 to 7 months in the woodland types to approximately 3 months in the high alpine types.

Electrical storms present a serious fire problem in summer, particularly in some localities, because they are usually accompanied by little or no precipitation. They are particularly serious during August.

Wind movement on the average is moderate. The average wind velocity is less than 10 miles per hour (Weather Bureau 1926). High winds having a velocity of more than 40 miles per hour occur occasionally. The prevailing winds are from the west, although they are diverted to some extent by the Coast Ranges.

Development of Lumbering

The first lumbering operations in this region began in 1848 with the establishment of a small sawmill at Coloma, Eldorado County, coincident with the discovery of gold at the same place. Shortly after this, several more sawmills were established to meet the needs of the mining communities. From 1860 to 1880 several circular mills started operations on Lake Tahoe to supply lumber to the western Nevada mining communities. Most of the early operations were on a small scale, principally to supply the local demands. Just before 1870, with the advent of the Central Pacific Railroad, the first large-scale operations started near Truckee, California. About 10 years later, when the California and Oregon Railway was completed, large operations got under way in the northern counties. By 1900, lumbering was an important industry, and large operations were numerous. In recent years the cut of saw timber has been between 2,000,000,000 and 2,500,000,000 board feet annually. More than 50 per cent of the cut is concentrated in thirteen sawmills. Only a few sawmills cut over 50,000,000 board feet a year.

In 1948 it was estimated that the region contained approximately 5,400,000 acres of virgin timber, of which 1,352,000 acres were either withdrawn from use for commercial timber production or considered unavailable for such a purpose. In recent years the area of virgin forests has been reduced by cutting by approximately 150,000 acres annually. Cutting of second-growth forests and second cutting of residual stands are becoming increasingly important. In 1946 such cuttings covered 39,477 acres. Lumber has been, and still is, the principal product of the forest. For a short time during the Civil War some naval stores were produced locally (Smith 1914).

The Effect of Past Practices

A considerable acreage of private lands cut over before 1925 was handled so badly that the land supports little valuable tree growth, and natural re-establishment of a profitable stand is exceedingly slow

(Fig. 83). Various estimates place the amount of this type of cut-over land at 40 to 60 per cent of the total. Pine stands suffered more than mixed conifer stands, because cutting removed more completely the trees from the former. In the mixed conifer stands, occasional seed-producing trees were left.

Of greater importance than close cutting in depleting this growing stock of many private cut-over lands were the destructive logging

Photograph by U. S. Forest Service.

FIG. 83. A severely burned area in the ponderosa pine type on which shrubs (snowbrush and manzanita) are so dense that tree reproduction will be very slow in becoming established.

methods and slash disposal technics frequently in use. Power skidding broke down a large proportion of the saplings and poles and uprooted extensive areas of reproduction. Logging was frequently followed by either intentional or accidental broadcast burning of the slash. All areas with such a history were partly denuded. Subsequently they have grown up chiefly to shrubs (Sterling 1904). Those lands usually do not reproduce naturally. In contrast, lands that escaped destructive logging and slash disposal support a light stand composed chiefly of low-value species.

Some operators practiced "light burning" in their uncut timber on the theory that it was a desirable fire-prevention measure that did no damage (California Forestry Committee 1923). It failed as a fire-prevention practice, for new inflammable material soon covered the

ground (Show 1915). Furthermore, it caused soil deterioration, the loss of practically all small reproduction and some larger trees, the creation of fire scars on trees not previously damaged, and the enlargement of old scars, which subsequently led to windfall, on trees wounded by previous fires (Boerker 1912, Pratt 1911, Show 1915).

Since 1925 forestry practices on most of the private lands have gradually improved. Better fire protection since 1925, less destructive logging since the introduction of the tractor in 1926 (Fritz 1930), and selective cutting since 1931 have contributed to the improved condition of cut-over land. Some operators are leaving many trees, 12, 14, and even 16 inches d.b.h., as a nucleus for a second cut. These merchantable trees and the young growth, saved in logging by the use of ground skidders and tractors, form a larger reserve stand than formerly, but they still are inadequate for an early second cut. Partial piling and burning, augmented by cooperative fire protection with the U. S. Forest Service and the state, provide better protection for cut-over lands than formerly.

Cutting and protection on the national forests have always been of a high order, resulting in a productive condition of cut-over lands. Some of the earlier cut-over lands, because they support a heavy reserve stand, are not yielding as much net growth as those cut over more recently. This difference is particularly noticeable on the first cuttings, which removed pine to a diameter of 36 inches d.b.h. and fir and cedar to 18 inches (Woodbury 1930*a*). Major emphasis was placed on the retention of a large reserve stand and securing regeneration. In recent years the objective has been to leave the maximum volume of thrifty trees capable of rapid growth as well as good seed production and to cut only the more defective fir and cedar. A second cutting is thereby possible in about 30 years. This policy is resulting in improved productivity of cut-over lands.

Logging has been done carefully on the national forests, and thus unnecessary damage to young growth has been avoided. Likewise, every effort has been made to protect all lands from fire. Slash disposal in the form of complete piling and burning has given effective protection to cut-over lands. Experimentation with partial piling and burning of slash, followed by special protection on two large areas, has proved the feasibility of this form of protection on cut-over lands of moderate fire hazard and suggests wider application in the future.

Destructive fires are responsible for the denuded land area estimated at 300,000 to 2,000,000 acres. Little work has been done to restore this land to production. The first effort by the Forest Service during

the period 1908 to 1913 in the form of direct seeding of approximately 3600 acres was unsuccessful because of destruction of seed by rodents and/or excessive competition of shrubs with tree seedlings.

By 1948, approximately 17,000 acres of successful plantations had been established, and 4763 acres had been seeded, of which 2139 acres were satisfactory.

THE FORESTS AND THEIR MANAGEMENT

The forests of the California pine region are composed of many species, two to five of which are commercially important, occurring in a variety of combinations to constitute many distinct forest types.

The local occurrence of the individual types is correlated with differences in altitude, aspect, and precipitation. The most important timber types from the standpoint of their present commercial value are the Pacific ponderosa pine, the ponderosa pine–sugar pine–fir, and the Pacific ponderosa pine–Douglas-fir types. The silviculture of these types only is presented below. Other types, occupying in the aggregate a vast area but having little commercial value at present, are scattered through the region. Of the secondary types, Douglas-fir is the most valuable commercially at present, chiefly in the northern Sierra Nevada, especially where ponderosa pine is a component of the stand. It is intermingled with the ponderosa pine type there, occupying north slopes and deep canyons.

The red fir and white fir types occupy the high and middle altitudes, respectively, of the Sierra Nevada. They are composed chiefly of the firs that give them their names, but Jeffrey pine, western white pine, lodgepole pine, mountain hemlock, Douglas-fir, ponderosa pine, and sugar pine may be associates. Because of their inaccessibility and highly defective condition, these forests have little commercial value at present. Potentially they have value for paper pulp, but their use for this purpose does not appear likely for many years because certain economic and physical factors militate against it (Woodbury 1930*b*).

The woodland types, characteristic of the low altitudes, are valuable chiefly for watershed protection and as local sources of fuel and fence-post material. The types are many: the California black oak, canyon live oak, and digger pine–oak are characteristic of the lower west slopes of the Sierra Nevada; the Sierra juniper and pinyon-juniper types, of the Modoc Plateau and Shasta Valley; and the oak-madrone type, of the northern Coast Range.

The lodgepole pine type occurs on flats at 5500 to 6000 feet in the northeast part of the region and at 6000 feet in the Sierra Nevada. At the highest altitudes, the whitebark pine and fir types (previously mentioned) occupy extensive areas. These types are valuable chiefly for watershed protection.

PACIFIC PONDEROSA PINE TYPE

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of Forest

Importance.
  Area—Major.
  Commercial Value—High.
Sites Occupied—On relatively dry sites over a wide range in elevation from 1000 to 7000 feet in different parts of the region; along east side of Sierra Nevada, and in northeast part of region, 5000 to 7000 feet; in northwest part of region down to 1000 feet; south and west aspects of west slope of Sierra Nevada in southern part of region up to 6000 feet.
Associated Species.
  Major—Ponderosa pine (pure over extensive areas).
  Minor—Douglas-fir, California incense-cedar, sugar pine, white fir.
Place in Succession—Permanent type, except on better sites, where it is replaced by other species.

Virgin uneven-aged stands predominate. They contain a predominance of mature and overmature trees. Some of the older trees attain diameters of 5 to 6 feet. The forests of the west slopes contain many trees over 30 inches d.b.h.

There is a considerable acreage of even-aged second-growth forest, much of it of merchantable size.

Cut-over lands vary from the selectively cut forests on the national forests which are fairly well stocked with reproduction, saplings, poles, and young timber to the sparsely stocked unburned clearcut forests on privately owned lands and partially or completely denuded burned-over lands.

Stand Regeneration and Development. *Advance Reproduction.* In general, advance reproduction in the old-growth forests is deficient, except where California incense-cedar and white fir are components of the stand—advance reproduction of these species being fairly abun-

dant. Stands recently subjected to light burning support little or no reproduction.

TABLE 32

THE CHIEF CHARACTERISTICS OF DUNNING'S TREE CLASSES FOR PONDEROSA PINE

Tree Class	Age Class	Crown Dominance *	Crown Length †	Crown Width	Form of Top	Vigor
1	Young or thrifty mature	Isolated or dominant	65% or more	Average or wider	Pointed	Good
2	Young or thrifty mature	Usually codominant	Less than 65%	Average or narrower	Pointed	Good to moderate
3	Mature	Isolated or dominant	65% or more	Average or wider	Round	Moderate
4	Mature	Usually codominant	Less than 65%	Average or narrower	Round	Moderate or poor
5	Overmature	Isolated or dominant	Any size	Any size	Flat	Poor
6	Young or thrifty mature	Intermediate or suppressed	Any size, usually small		Round or pointed	Moderate or poor
7	Mature or overmature	Intermediate or suppressed	Any size, usually small		Flat	Poor

* There are some minor exceptions in classes 1, 2, 3, 4, 5.

† When expressed in percentage it refers to the proportion of the total height of the tree.

Subsequent Reproduction. The establishment of reproduction after the cutting of an old-growth forest is, at best, a slow process, the infrequency of large seed crops and severe climate, particularly the precipitation factor, being significant factors. Ordinarily fairly good seed crops are borne by mature ponderosa pine trees every 3 or 4 years, but sometimes 5 to 8 years may elapse between large crops. Seed production is related to various characteristics of the tree—chiefly age,[1] crown dominance, crown size, and general vigor. Dunning's tree classification, presented in Table 32 and Fig. 84, is the basis for an under-

[1] In application, diameter is used as a guide, because diameter and age are more or less directly related when site or tree condition are not limiting.

standing of seed production and other silvical characteristics of ponderosa pine (Dunning 1928).

Tree classes 3, 4, and 1, in the order named, class 3 being the greatest, are the best seed producers, and, with the exception of class 4, they have other desirable characteristics (see pp. 482, 488). Class 5 trees are actually superior to classes 3, 4, and 1 as seed bearers, but they

Photograph by U. S. Forest Service.

FIG. 84. The seven tree classes of ponderosa pine recognized by Dunning.

represent too large and too insecure an investment in high-quality timber to be retained for seed. Seed production of individual trees in a tree class varies with the tree's diameter; trees under 18 inches d.b.h. generally bear only light crops, but above this diameter seed production increases rapidly with diameter increase. Although at one time three trees over 20 inches d.b.h. were regarded as sufficient to produce a supply of seed adequate for successful regeneration, if other factors did not interfere,[2] present-day silviculturists believe that more trees are needed as a minimum.

[2] Rodents, particularly the chipmunk, Sierra chickaree, white-footed mouse, and California ground squirrel, often consume vast quantities of seed, thus interfering with regeneration.

Next to drought, which cannot be controlled, competition from other vegetation, trees included, interferes most with the establishment of ponderosa pine seedlings. Shrubs, particularly abundant on sites that have been frequently burned, are a real obstacle to seedling establishment, probably because they withdraw much moisture from the soil and cast too heavy shade (Fig. 83). Locally one of the low perennial plants, squaw carpet, apparently aids ponderosa pine establishment, because it protects the seedlings from fire and grazing (Dunning 1923). Present evidence indicates that ponderosa pine reproduction succeeds best where competition from other vegetation is least (Baker 1942).

Whether grazing by domestic livestock is inimical to regeneration is not definitely known, but present evidence indicates that in northeastern California cattle are not a serious menace to young seedlings,[3] but locally they may be detrimental. (In this connection, see p. 489.)

If such tolerant species as California incense-cedar and white fir are represented in the stand, the control of the composition of the reproduction stand is not an easy matter. However, in stands in which cutting has reduced the proportion of fir and cedar in the reserve stand and has created a fairly open site, the pine has generally maintained and, in some cases, increased its representation in the reproduction stand (Dunning 1923, Woodbury 1930*b*).

Height-growth differences of seedlings of the various species, exclusive of the California incense-cedar, which grows slowly, are not great enough to give any species a significant advantage. When competition enters into the picture, the advantage of white fir and California incense-cedar, because of their greater tolerance, becomes more apparent. Ponderosa pine seedlings may persist for many years under intense competition, but their growth is slow, and ultimately they succumb.

Growth and development of the reserve stand depends to a considerable extent on the relative proportion of the different tree classes that comprise it. Class 1 trees are superior to all others in growth and mortality risk. In order of rate of diameter growth (after class 1, from the fastest to the slowest), the tree classes fall as follows: class 6,[4] class 2, class 3, class 7, class 4, class 5. The tree classes rank in the following order as mortality risks (from low to high risk): class 6, class 3, class 2, class 5, class 4, class 7.

[3] This and other statements in this chapter are based on annual and other reports prepared by the California Forest and Range Experiment Station, Berkeley, Calif.

[4] Only if released; otherwise, its growth is very slow.

Acceleration in growth after cutting occurs only when a tree is released by the cutting of at least one tree within 50 or 60 feet of it. Growth of trees in groups gradually declines (Dunning 1923).

Obviously satisfactory development of the reserve stand is dependent on an adequate number of good trees, particularly class 1 trees, properly released.

Windfall. Windfall is a minor factor in virgin forests. In the cut-over forest a released tree that originally grew in a clump of trees is very susceptible to windfall during the first few years, but if it survives the first 5 years after cutting it is not likely to be windthrown thereafter.

Economic Basis

Utilization and Marketing Problems. Profit in utilizing the ponderosa pine type hinges on the large proportion of ponderosa and sugar pine, the most valuable species, in these forests. Although many of the old-growth cedars are defective and cannot be utilized for lumber, they can usually be cut into pencil stock. The advance in the price of California incense-cedar wood in recent years indicates that potentially cedar is a valuable tree. Douglas-fir is marketable, but its value is generally low. Most of the large old-growth white fir trees are so defective that they have little or no commercial value.

Because of the rough topography and long distance to market, logging and transportation costs are comparatively high; therefore, the marginal tree is large. In one case ponderosa pine trees less than 22 inches d.b.h. yielded lumber worth less than the cost of production (Brundage, Krueger, and Dunning 1933). In another case the size of the marginal tree was found to be 24 inches d.b.h. (Sanford 1930). In the first instance the size of the marginal tree for other species was as follows: sugar pine,[5] 23 inches d.b.h.; California incense-cedar, 28 inches d.b.h.; white fir, 34 inches d.b.h.

In logging-cost study on the Lassen National Forest, wide differences were found in the felling and bucking time required for trees of different sizes. Based on the time required to fell and buck 16-inch trees, 20-, 30-, and 40-inch trees required approximately 45, 23, and 17 per cent as much time to complete the operation (Hasel 1946). These differences would have a strong influence on the cost of harvesting trees of various sizes.

Although there is considerable demand for certain low-grade forest products, notably box boards, there is little opportunity at present for

[5] In some cases sugar pine can be utilized profitably to a somewhat smaller diameter than ponderosa pine.

utilizing small trees profitably because the material can be secured more economically from the poor-quality portions of saw-log trees. This situation is likely to change, when, through improved transportation facilities and the development of new equipment and methods, logging costs are lowered.

Growth and Rotation. For most sites it appears that a rotation of 120 years is more economical than shorter or longer rotations. Rotations of as much as 150 years are probably necessary on the poorer sites. A fully stocked stand on an average site (site III) produces a mean annual growth per acre of approximately 340 board feet, Clark International rule, ⅛-inch saw-kerf, on a 120-year rotation (Show 1925).

Of the species associated with ponderosa pine, two, sugar pine and white fir, and probably a third, Douglas-fir, make faster growth than ponderosa pine (Dunning 1923). California incense-cedar makes slower growth. Growth of ponderosa pine, studied in considerable detail, is dependent on the character of the tree and the amount of its release (see p. 482).

Financial Aspects. Timber values are affected by the proportion of the stand volume that is removed and by the types of trees that are cut. Price (1924) found that lumber value per thousand board feet was increased approximately 5 per cent when 63 per cent instead of 100 per cent of the merchantable volume of a stand was removed. Hasel (1946) found minor differences in logging costs when 2835, 9174, and 13,022 board feet per acre were cut. He found that differences in cost were due chiefly to tree-size make-up of the stands. Therefore, if the light cut would remove the larger trees of high quality, net profits from such cuts could easily be greater than those from heavier cuts because of the greater value of the lumber.

Application of Methods

Old-growth ponderosa pine forests can be handled most advantageously by the selection method of cutting. Since the forests are very irregular in their tree- and size-class composition from acre to acre, the cutting must be varied accordingly. Selection of trees for cutting should be based on Dunning's tree classification and the size of the marginal tree.[6] On this basis the proportion of the stand that should

[6] Since the size of the marginal tree is determined, at least in part, by operating methods and efficiency, it varies on different operations and should be determined for each operation, or better still, for parts of operations that may be sufficiently different.

be removed varies from 50 to 90 per cent of the merchantable volume. Trees below the marginal size should be cut whenever their removal will improve the growth or silvicultural condition of the stand, including susceptibility to insect attack (see p. 488).

Although local circumstances alter actual tree selection, tree classes 4, 5, and 7 should, as a general rule, be cut. However, if a seed tree is needed and better trees are not available, a class 4 or class 5 tree should be retained, the best tree available being chosen, of course. Class 1 trees should always be left. Class 2 trees should be retained, unless class 1 trees are so numerous that the stand will be benefited by the removal of some trees of the former class—a condition that is not often encountered. Class 3 trees should be left with discretion. They may be retained as seed trees—trees between 20 and 30 inches d.b.h. are preferred—when class 1 trees are not available. If the cutting cycle is to be short, not over 30 years, the better class 3 trees can be retained in any number needed to build up an adequate volume in the reserve stand. Class 6 trees should be retained if they will be released in cutting, or if they are too small to be utilized. If tree selection takes into consideration established foliage and twig characteristics that indicate the degree of bark beetle risk each tree represents, the cutting can aid materially in reducing the losses from bark beetle attacks (Salman and Bongberg 1942).

Situations requiring special attention are clumps of merchantable trees, areas well stocked with young growth, and defective trees. A single tree of a clump should not be left, because of the windfall danger. The decision as to whether a tree should be cut to release young growth should be based on the relative future value of these elements in the stand and the silvicultural condition of the tract. Trees with such defects as spike top, serious frost or lightning cracks, large fire scars, severe rot, or active insect infestation should be cut regardless of their tree class or the silvicultural condition of the stand.

Until more is known about its technic, thinning should be confined to immature groups in which trees large enough to produce saw logs can be removed during the reproduction cutting. Class 1 trees should be favored.

Planting. Planting, for the present, is recommended only for denuded land. It may be a desirable practice on other types of areas at some future date, but it is too uncertain to justify a recommendation for its more general use.

Two-year ponderosa pine transplant stock [7] is suggested for general use. Sugar pine may be employed on the more moist sites, such as certain north slopes. Planting in spring, as soon as possible after the snow melts, is recommended, a spacing of 6 by 6 feet being advisable.

Inconclusive results have been obtained in limited trial of direct seeding (Keyes and Smith 1943).

Slash Disposal

Slash in Relation to Fire

Potentially slash resulting from cutting old-growth ponderosa pine forests is very hazardous, because the physical and climatic conditions create a natural fire hazard that is the greatest of any forest type in the region (Show and Kotok 1929, 1930). The heavy snowfall mashes the slash down quickly, thus rapidly reducing the hazard somewhat, but the decay of slash is very slow. Slash increases the fire hazard for about 10 years (Show 1926).[8]

Ecological Effects of Slash and Slash Burning

There is no evidence in this region to indicate the extent to which slash may be beneficial or harmful to reproduction. It has been demonstrated that of the methods involving slash burning, only the various forms of piling and burning (swamper burning included) conserve adequately the established young growth (Show 1926).

Economic Considerations

The method of partial piling and burning, supplemented by a system of fire breaks and special protection, costs 50 to 60 per cent as much as complete piling and burning. On areas of less than average fire hazard, the former method gives as effective fire protection as the latter.

Application of Methods

The method of complete piling and burning is recommended where the fire risk is high (e.g., where the lightning hazard is great) or where recreation is an important land use (Fig. 85).

[7] 1-1-1 stock gives higher survival than 1-1 stock, but its cost is too great to justify its employment (Show 1930).

[8] A more recent report (Woodbury, Burnett, and Edmonds 1935) estimated that the hazard might last for 13 years; but, since the slash in this particular experiment was created in, and during its first few years was subjected to, abnormally dry weather, 10 years may be a better estimate for average conditions.

The method of partial piling and burning is recommended where the fire hazard is below the average. Approximately 20 to 25 per cent of the slash should be piled and burned, this disposal being applied on strips 100 to 200 feet wide along roads, railroad rights-of-way, and trails in such a way that the cut-over land is divided into areas averaging not more than 160 acres. On these strips reproduction clumps and shrubs should be cut and burned with the slash. Pole and sapling

Photograph by U. S. Forest Service.

FIG. 85. Piled slash to be burned later in this cut-over ponderosa pine stand.

stands within the strips should be thinned and pruned (Woodbury, Burnett, and Edmonds 1935). At both edges of the strip debris should be cleared away to the mineral soil on a strip 4 feet wide. Intensive protection must be in effect for 10 years.

Disease and Insect Problems

Ecological Basis

The *western pine beetle* is a troublesome and, periodically, a very damaging pest on ponderosa pine. Always present in endemic form, attacking slow-growing trees either singly or in small groups, the beetle suddenly reaches the epidemic stage when natural factors favor

a substantial increase in insect population (Miller 1926), and, then, fast-growing as well as slow-growing trees are attacked in groups of 50 to 100 trees (Craighead, Miller, Evenden, and Keen 1931). Subsidence of an epidemic is most prompt and pronounced when critically low temperatures occur during winter (Miller 1933). In the winter of 1932, 64 per cent of a western pine beetle population was killed in a 3-day period during which the maximum temperature was 12° F. and the minimum −19° F. There was a temporary reduction in the infestation of trees. During epidemics, most severe and frequent on the Modoc Plateau and the west slope of the Sierra Nevada in the southern part of the region, the loss of merchantable timber may be 15 per cent by volume in a single year, and 50 per cent during a 5-year period.

As previously indicated, the less vigorous trees are ordinarily the most susceptible to attack. This is shown in a concrete way by the liability of the different tree classes to loss, shown as follows in order from the lowest to the highest liability to loss: class 1, class 2, class 3, class 5, class 6, class 4, class 7 (Dunning 1928). Infection with mistletoe or rot-producing fungi does not increase susceptibility to attack by the western pine beetle (Hopping 1925).

Rot, probably mainly *western red rot,* is common in fire-wounded trees (Boyce 1920, Mienecke 1916), but the percentage of defect from this source is not large.

Brown stringy rot and other rots are prevalent in white fir trees of saw-log size or larger. Mature and overmature trees usually contain so much rot that they are unmerchantable. California incense-cedar is equally defective.

Mistletoe attacks ponderosa pine trees to a limited degree quite generally but is a serious pest only on poor sites.

Control Methods

Control of damage by the western pine beetle should be focused, first of all, on prevention. Light sanitation-salvage cutting that removes the high- and very high-risk trees in a light cut is effective but practicable only where accessibility keeps logging costs low (Keen and Salman 1942, Salman and Bongberg 1942).[9] Much can be accom-

[9] High-risk trees have the following characteristics: foliage, at least over a considerable portion of the crown, average in length or shorter than average; foliage complement (needles per twig) less than normal, thin, bunchy, and unhealthy; foliage color fair to poor; some to many twigs lacking foliage, fading or dead, often localized to form "weakened" portions of the crown. Very high-risk

plished in the regular reproduction cutting to reduce beetle damage if trees are carefully selected (see p. 485).

The *black bellied clerid* (*Thanasimus leconti* (Wolc.)), which feeds on the western pine beetle, shows promise as a supplement to bark beetle control (Person 1940).

When epidemics occur in large tracts of commercial timber, special control measures must be applied (Craighead, Miller, Evenden, and Keen 1931; Miller 1926). Treatment of the entire infested area in a single season is most effective. Subsequent, or maintenance, control is justified only when more than five trees per section are infested, unless stumpage is worth at least $7.00 per thousand board feet—a value realized only on the most accessible tracts.

If, during winter control operations, the temperature falls to or below the lethal point for the insects, operations can be suspended for that year at least.

Mistletoe and rots can be controlled to a certain extent by judicious cutting.

Control of Animal and Logging Damage

Good range management, which gives recognition to number and class of animals in relation to the range's type of vegetation and carrying capacity, proper seasonal use, and uniform distribution are essential to the prevention of unnecessary damage to young growth and the site by livestock. It is necessary to be constantly on the alert for evidence of local injury in order that, if such occurs, corrective measures can be applied.

The severe logging damage of the past (see p. 476) is ample evidence that planning and supervision of logging are necessary if avoidable destruction is to be prevented.

Where a high-lead power skidder is used, main and secondary roads must be planned in advance and occasional high stumps should be left in strategic places to shunt logs around young growth, which practice reduces not only damage but logging costs as well (Hurt and Jones 1930).

Planning and supervision of logging are equally important where tractors and fair-lead arches are employed.

trees have the following characteristics: foliage mostly unhealthy, needles short, color poor, needle complement sparse over considerable portions of crown; some to many twigs and branches dead or dying; portions of crown definitely weakened; active top killing or partial infestations often present.

PONDEROSA PINE–SUGAR PINE–FIR TYPE

Composition and Character of Forest

Importance.
  Area—Major.
  Commercial Value—High.
Sites Occupied—3000 to 6000 feet in the Sierra Nevada between the Pacific ponderosa pine type below and the red fir type above (Committee on Western Forest Types 1945).
Associated Species—Five species occur in variable combinations.
  Major—Ponderosa pine, Douglas-fir, sometimes sugar pine.
  Minor—California incense-cedar, white fir, sugar pine.
Place in Succession—Climax type.

The Pacific ponderosa pine–Douglas-fir type is associated with the ponderosa pine–sugar pine–fir and the Pacific ponderosa pine type and has some of the characteristics of the former (Committee on Western Forest Types 1945). The type is distinguished by the predominance of ponderosa pine and Douglas-fir, but neither species is present to the extent of 80 per cent. White fir, California incense-cedar, sugar pine, and a wide variety of other conifers and oaks are often included in small amounts. Its successional position is uncertain.

This type exists as uneven-aged virgin stands and as cut-over land. The virgin stands contain a great proportion of large mature and overmature trees 4 to 5 feet in diameter. In general, they produce large volumes, 40,000 to 50,000 board feet per acre being fairly common (Fig. 86). Cut-over lands are in much the same condition as those of the ponderosa pine type, except that they support more large unmerchantable trees.

Stand Regeneration and Development. *Advance Reproduction.* Advance reproduction, chiefly firs and California incense-cedar, is generally abundant in old-growth stands. Ponderosa and sugar pine young growth is found only in the forest openings (Cooper 1906).

Subsequent Reproduction. To secure a goodly amount of pine reproduction after cutting is not an easy matter. Neither of the pines is prolific. Sugar pine is a more regular seed bearer than ponderosa pine, producing some seed nearly every year and a good crop every 2 or 3 years (Woodbury 1930*b*), but even the good crops are relatively light. The low viability of sugar pine seed—often only 20 per cent of the seed is viable—and the exacting seed-bed requirements of the seedlings—moisture and protection—are probably the main factors

that militate against generous reproduction.[10] Exposure of the site is inimical to seedling establishment.

One of the real obstacles to the establishment of sugar pine seedlings on many sites is the stand of advance fir and cedar reproduction. Any pine seedlings that do get started are doomed from the start because of their intolerance and the height advantage of the advance growth. Wherever sugar pine seedlings start on an open site at the

Photograph by U. S. Forest Service.

Fig. 86. A virgin stand of ponderosa pine–sugar pine–fir forest. Such stands produce large volumes of saw-timber.

same time as other species, they can hold their own because their growth is not exceeded by that of their associates.

Competition from other species is probably the chief limiting factor in preventing abundant reproduction of ponderosa pine.

California incense-cedar is believed to be prolific, bearing large crops every few years, at least. Cedar seedlings start in large numbers, but as they pass the seedling stage mortality is great, a peculiarity that has not been fully explained. Before the heavy seedling losses, the cedar offers considerable competition to the pines, but, if

[10] At one time (1914) two observers (Berry 1914, Jotter 1914) attributed the failure of sugar pine reproduction to the great destruction by the California gray squirrel (then very abundant) of sugar pine cones before they matured. This was quickly refuted (Miller 1914), and since pine seedlings are still sparse, even though the squirrel is nearly exterminated by hunting and disease, other factors must be the direct contributing cause.

the latter can survive the early competition, the cedar gradually becomes less troublesome, because of both its relatively slow growth and its decreasing number.

Douglas-fir reproduces comparatively well. A site with exposed mineral soil and a partial canopy to protect the soil and thus maintain the proper balance in moisture is ideal for the establishment of Douglas-fir seedlings. During the seedling and sapling stages Douglas-fir is sufficiently tolerant to withstand considerable competition, but later its tolerance decreases, when the balsam firs gain an advantage.

The firs are prolific but they reproduce poorly, frost probably being a significant factor. The firs gain their chief advantage from their abundant advance reproduction, which responds quickly to release, thus maintaining their dominant position in the reproduction stand after cutting. Light partial cutting probably gives the firs a greater advantage over the pines than heavy partial cutting or clearcutting, because the pines owe their existence to the minimum competition.

Obviously the maintenance of a stand composed mainly of the high-value species is beset with many problems, most of which are poorly understood.

Windfall. Windfall is not serious, either in virgin or cut-over stands. Trees isolated by cutting are most susceptible to windthrow.

Economic Basis

There is no information on the economic aspects of silviculture in the California pine region that applies specifically to the ponderosa pine–sugar pine–fir types. Only a few generalizations can be made, chiefly by way of comparing this type with the ponderosa pine type. The high abundance of balsam firs and California incense-cedar trees, which, as previously indicated (p. 483), are very low in commercial value in the old-growth forests, accentuates the utilization problem. It is well to bear in mind, however, that sound California incense-cedar is not in the same class as defective old-growth cedar. Because of the prevalence of low-value species in most of the ponderosa pine–sugar pine–fir forests, the marginal tree is probably somewhat larger than in the ponderosa pine type (see p. 483).

Growth in general is faster than in the ponderosa pine type because the ponderosa pine–sugar pine–fir types occupy more moist sites.

Application of Methods

In view of the difficulties in increasing, or even in maintaining, the proportion of the more valuable species in the old-growth forests and

the meager data on the ecology and economics of the ponderosa pine–sugar pine–fir type, recommendations on cutting must be general and conservative.

The objectives of favoring the high-value species, sugar pine and ponderosa pine, securing satisfactory increment, and realizing a mod-

Photograph by U. S. Forest Service.

FIG. 87. A reserve stand of approximately 13,000 board feet per acre, which represents 36 per cent of the original volume of a stand in the ponderosa pine–sugar pine–fir type. Sugar pine is the most abundant species.

erate profit can probably be served best in old-growth stands by selection cutting. With these objectives in view, the high-value species should be cut as lightly, and low-value species as heavily, as economic conditions will permit (Fig. 87). Ponderosa pine should be retained on the basis of tree classes, as outlined for the ponderosa pine type

(p. 484). Although there is no tree classification for sugar pine, it is probably safe to select sugar pine trees on the same basis as ponderosa pine. For all species the cutting of sound trees should take into consideration the size of the marginal tree. Clumps of ponderosa or sugar pine young growth should be given every advantage possible by cutting merchantable trees that are suppressing them. Wherever it is obvious that the pines have little chance of succeeding, it is better to leave a reserve of cedar and Douglas-fir than to impair the timber-growing capacity of the site by close cutting.

Defective fir and cedar trees must be cut[11] even though they contain no merchantable material. The cutting of this material should be postponed until after logging is completed.

Denuded areas should be planted with ponderosa pine, sugar pine, and California incense-cedar on the respective sites to which each is well adapted.

Slash Disposal

The fire hazard is exceptionally acute in the ponderosa pine–sugar pine–fir type because of the severe lightning menace (Show and Kotok 1929). This factor obviously makes the natural hazard of this type higher than that of the ponderosa pine type. Offsetting it, however, is the more rapid decomposition of the slash in the ponderosa pine–sugar pine–fir type than in the ponderosa pine type. The slash fire hazard is negligible after 8 years.

Because of the similarity in the slash problems of the ponderosa pine–sugar pine–fir and ponderosa types, the same methods of disposal can be used in the former as in the latter (see p. 486). Somewhat greater emphasis, however, must be placed on piling and burning.

Disease and Insect Problems

Ecological Basis

The *white pine blister rust* first infected currant and gooseberry bushes and sugar pine in the northern part of the region and now constitutes a menace to the sugar pine, which is very susceptible to this disease.

Brown trunk rot is the chief wood-destroying rot on sugar pine trees, but the percentage of defect caused by it is small.

[11] Girdling is not permissible because the standing snags create a serious fire hazard.

Brown stringy rot in the firs and a rot caused by the *incense cedar fungus* in California incense-cedar cause a large loss of merchantable timber of these species. Overmature trees are usually so defective that they are worthless, whereas mature trees generally contain some sound wood.

The *western pine beetle*, infesting the ponderosa pine, and the *mountain pine beetle*, infesting the sugar pine, each year kill occasional mature or overmature trees. The normal loss amounts to about 1 per cent of the merchantable volume annually, but during epidemics, which usually last 2 or 3 years, the loss increases to 2 or 3 per cent (Craighead, Miller, Evenden, and Keen 1931). Large sugar pine trees are generally attacked in their tops, the insect gradually working down the trunk and killing the tree. An instance of severe damage to ponderosa pine by the mountain pine beetle has been reported in an overstocked 45-year-old stand originally composed of equal amounts of ponderosa pine and white fir (Eaton 1941). The damage is attributed to the weakened condition of the trees caused by the intense competition between trees and to drought conditions.

Control Methods

Wherever the representation of sugar pine is large, currant and gooseberry bushes should be eradicated; but there is insufficient evidence to indicate the minimum amount of sugar pine a stand must contain to justify the eradication cost. Eradication should precede logging, because the cost is only one-fourth to one-half as much in uncut stands as in cut-over stands (Benedict and Harris 1931).[12]

The problem of rot is primarily a matter of salvage or disposal which can be best cared for during cutting (see p. 494).

Control of the western pine beetle and mountain pine beetle should follow the plan outlined for the ponderosa pine type (p. 488).

Control of Animal and Logging Damage

See the recommendations for the ponderosa pine type (p. 489).

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15 • *Northwest Ponderosa Pine Region*

DESCRIPTION AND HISTORY

Location and Landownership

The northwest ponderosa pine region as recognized in this publication includes the timbered lands of eastern Oregon and Washington, except the extreme northeastern part of Washington (which lies in the northern Rocky Mountain region) and a portion of southwestern Idaho (Fig. 1).

The forest-land area is approximately 27,000,000 acres. Range and agricultural land, confined to definite climatic zones outside the forest areas, make up an additional 64,000,000 acres. The forests occupy two belts: (1) the east slope of the Cascade Range and adjacent plateaus and (2) the Blue Mountains and Salmon River Mountains and adjacent outlying ranges. These two areas are completely separated by a vast treeless belt occupying the entire central portion of Oregon and Washington. The forest lands cover almost solid blocks, broken only by small cleared farm lands.

A large proportion of the forest land—approximately 14,000,000 acres—is publicly owned and administered chiefly as national forests and Indian reservations. The national forests are being enlarged gradually by the acquisition from private owners of the more productive cut-over land.

Physiographic Features

The topography of the northwest ponderosa pine region is diversified. Level plateaus, mountains with long gentle slopes, and rugged mountain peaks with precipitous slopes are represented. Extending east of the Cascades slopes in central and southern Oregon and southern Washington lies the Columbia Plateau, a considerable area of which is forested. Its flat terrain, at an altiude of 2500 to 5000 feet, is

broken by numerous low volcanic cones with gentle slopes. The Cascade Range rises from the Columbia Plateau on the west, becoming increasingly rugged at the higher elevations, and finally terminating in the summit of the range, where rough peaks rising from 9000 to 12,000 feet are numerous. In northern Washington the Okanogan Mountains, lying mainly between 2500 and 6000 feet but with several peaks rising to 9000 feet, join the Cascade Range on the east, forming an unbroken chain of mountains between the Cascade Range and the Okanogan River (Bowman 1911).

In eastern Oregon and southwestern Idaho the Blue Mountains and the Salmon River Mountains, with gentle to abrupt slopes, stand out prominently above the surrounding plains. The numerous peaks, rising to 8000 and 9000 feet and occasionally higher—3000 feet above the general contour—give these mountains an irregular, rugged appearance. Numerous streams disect the mountains.

Pumiceous soils made up mostly of gravel, sand, and volcanic dust characterize central Oregon. Great depth is typical of these soils where the land surface is level. On the steeper slopes of the Cascade Range rock outcrops are in evidence. The surface soil is unusually fine-textured because of the large portion of volcanic dust in it. Gravel is prominent at a depth of 2 to 3 feet in some sections. Free drainage made possible by the very porous character of the soil accentuates the dryness of the climate.

The soils of the northern Cascades, the Blue Mountains, and Salmon River Mountains are derived chiefly from granite, schist, basalt, and slate, which through decomposition have formed sand, sandy loams, and clays (Bowman 1911). Erosion has kept the soil from attaining great depth, especially on the steeper slopes. Stones and boulders are abundant in most of the soils.

The Columbia River is the final drainage outlet for nearly the entire region. Draining into it from the north and west are the Yakima and Okanogan Rivers and from the south the Deschutes, John Day, and Snake Rivers. Each of these streams has numerous tributaries. The Klamath River, the chief stream of southern Oregon, flows out of the region into California.

Climatic Features

The climate is characterized by light rainfall, pronounced fluctuations in temperature, low relative humidity, rapid evaporation, and abundant sunshine (Weather Bureau 1926).

The mean annual precipitation for the more important areas of commercially valuable timber is 18 to 25 inches. In the high mountains it probably exceeds 50 inches. Sixty to seventy-five per cent of the precipitation occurs between November 1 and April 30, mostly as snow. The amount of snowfall varies from an average of 44 inches per year at Bend, Oregon, to more than 200 inches in the high mountains of the Cascade Range. July and August, with less than 1 inch of rain per month, are the driest months. June and September are dry in most localities, but less so than the midsummer period. Some sections receive fairly good rains in May and June.

The atmosphere is relatively dry at all times, but particularly so during the summer months. The relative humidity varies from 30 to 70 per cent in summer, but short periods when the humidity ranges from 15 to 30 per cent during the driest part of the day are frequent. During the other seasons, the humidity may be as high as 85 per cent.

The summer is short. Diurnal changes in temperature in summer are normally wide, a midday temperature of 85° to 90° F. often being followed by an early morning temperature of 40° F. Frost may occur during any month of the year. Periods of excessively warm weather, when the temperature rises to more than 100° F., are usually of short duration. The mean temperature for July, the hottest month of the year, ranges from 58° to 69° F. at low to medium elevations.

The winters are cold but not severe. January, the coldest month of the year, has a mean temperature range of from 24° to 31° F. Occasional low temperatures of −20° to −30° F. are on record. Short periods when the temperature is above freezing occur from time to time during the winter months.

The average length of the growing season is between 3 and 5 months, varying with elevation and exposure.

Electrical storms, frequently accompanied by little or no precipitation, may occur between June 1 and September 30, but they are usually most frequent and critical from July 10 to August 15.

The wind movement is moderate. A wind velocity of 30 miles per hour has been reported frequently, and a few storms have been recorded with wind velocities of 50 miles per hour.

Development of Lumbering

Extensive lumbering began in the northwest ponderosa pine region rather recently. Numerous small portable sawmills were cutting lumber for local consumption as early as 1880. By 1890 extensive cutting

was in progress in connection with mining operations in eastern Oregon, particularly in the Sumpter Valley of the Blue Mountains. Shortly after 1900 mills were built at Baker, Oregon, and a few years later with the extension of the Sumpter Valley Railroad into the heart of the Blue Mountains a sawmill was set up at Austin, Oregon. Simultaneously, operations in the Salmon Mountains of Idaho increased. These enterprises were of medium size, most of them involving the cutting of 100,000 to 200,000 board feet per day. Other operations, somewhat larger than these, have developed more recently.

In 1914 extensive production began in southern Oregon and expanded rapidly, particularly on the Klamath Indian reservation. In 1948 eight timber contracts were in effect with an annual cut of approximately 100,000,000 board feet. During the previous 10-year period, the cut had averaged approximately 150,000,000 board feet annually.

With the completion of railroads from the Columbia River to Bend, Oregon, a new area of timber was opened in 1916. Two operations were immediately established there with a combined daily capacity of more than 1,000,000 board feet. Many of the operations in central and southern Oregon are large, and some of them have capacities up to 400,000 board feet per day.

Cutting in eastern Washington has not been so extensive as elsewhere. Stand conditions frequently do not warrant extensive or continuous operation. Small semiportable mills are more common in Washington than in Oregon.

In 1948, more than 200,000 acres of timberland were being cut annually, a large proportion of them privately owned.

The Effect of Past Practices

Cut-over lands are in many stages of productivity. Public lands have been carefully managed since cutting began, but private lands were given little care before 1925. The mixed stands on private lands have suffered the least because they usually contain a large proportion of small trees and inferior species, which are seldom cut. Although of low quality, these cut-over lands are at least reasonably productive. The ponderosa pine type has been exploited very extensively and depicts very vividly the lack of silvicultural practice. Early cutting removed practically all trees, since it included everything above 8 or 10 inches d.b.h. These lands support a stand fundamentally even-aged, except where fire has occurred (Weidman 1921). Unfortunately, de-

structive slash disposal, chiefly broadcast burning, used so widely in Oregon until 1925 and even more recently in Washington, virtually wiped out the forest growth over vast areas. Brush and grass have taken over much of this land, which in the absence of seed-bearing trees has little chance to reproduce naturally (Fig. 88). Since about

Photograph by U. S. Forest Service.

FIG. 88. Broadcast burning following virtually a clearcutting of all merchantable material from a ponderosa pine stand has left the land practically denuded. Such land has little chance to reproduce naturally.

1920, some operators have neglected to dispose of the slash on cut-over lands or have been excused from slash burning. Much of this acreage, because it has escaped accidental denudation by fire, now supports an excellent stand of thrifty reproduction, saplings, and poles. This land is not completely stocked with trees, for little or no subsequent reproduction has become established, but it is in sharp contrast to the burned land. Since 1925 strip burning and spot burning have, in large part, taken the place of broadcast burning. These methods destroy

only small amounts of forest growth, mostly seedlings, leaving the land partially productive.

Much of the land logged before the enactment of the compulsory slash-burning law supports an excellent stand of thrifty reproduction.

Cutting has been lighter in recent years. Occasional trees 12 to 14 inches d.b.h. are frequently left as a reserve stand, which under the improved fire protection of late years is more secure than formerly.

Management of the public lands always has had the objective of continuous production. Selection cutting has been fairly successful in reaching this goal. On the Indian reservations the earlier cuttings were so heavy that many young, rapid-growing trees were removed. On the other hand, cutting on the national forest lands frequently left many slow-growing mature trees. Both the Forest Service and the Indian Service have gradually worked toward retaining a thrifty reserve stand of as heavy volume as possible, with a result that until recently both were leaving a reserve stand that averaged, over large areas, approximately 20 per cent of the volume of the original stand (Fig. 91). Under this practice mortality from windthrow, disease, insects, and old age was kept at a minimum. Regeneration has been slow and uncertain, but it is doubtful whether any type of cutting that was economically feasible would have given improved results. The present trend, made possible by new developments in logging, is toward lighter cutting.

Before 1928, slash on publicly owned cut-over lands was disposed of almost exclusively by complete piling and burning. Gradually, partial piling and burning came into wider use. The lighter cuts under the selection system which were introduced in the late thirties create small volumes of slash. This has led to wider adoption of partial piling and burning, which apparently is proving effective in reducing the fire hazard on cut-over lands to a reasonably safe point.

Very little planting has been done because of the high cost and low productivity of the land. A considerable acreage of privately owned land that was severely cut and later broadcast burned must eventually be planted if the land is to be made productive. Planting on the national forests has been inconsequential, having been confined to approximately 2000 acres.

THE FORESTS AND THEIR MANAGEMENT

The forests of the northwest ponderosa pine region are comprised of five major types, which in Oregon and Washington constitute approxi-

mately 87 per cent of the forest land.[1] The major commercial timber type, ponderosa pine, occupies 13,200,052 acres of the total forest-land area of 24,729,995 acres in Oregon and Washington. The other major types in these states [2] are as follows: larch–Douglas-fir, 4,423,238 acres; lodgepole pine, 1,101,765 acres; woodland, 1,537,700 acres; subalpine, 1,290,985 acres. Miscellaneous forest types, most of them having little present commercial value, comprise approximately 3,000,000 acres. Virgin timber still predominates, and only in the ponderosa pine type is the area of virgin timber being substantially reduced each year. Limited cutting is in progress in some localities in the larch–Douglas-fir, lodgepole pine, and woodland forests.

INTERIOR PONDEROSA PINE TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest

Importance.
- Area—Major.
- Commercial Value—High.

Sites Occupied—Dry sites, at 3700 to 5700 feet in southern part of region, and 2500 to 4500 feet in northern part.

Associated Species.
- Major—Ponderosa pine, pure over extensive areas.
- Minor—Numerous species, varying locally. Some are major associates over small areas. Lodgepole pine, widely distributed; Douglas-fir, white fir, grand fir on cool, moist sites; sugar pine sparse in southern part of region; red fir, Pacific silver fir, California incense-cedar, western redcedar in higher Cascades; western larch in Blue Mountains and northern Cascades; curlleaf mountain-mahogany, Rocky Mountain juniper, and Sierra juniper on shallow rocky sites and lower elevations.

Place in Succession—Climax type at low to medium elevations. May be succeeded by larch–Douglas-fir type at higher elevations or on moist sites.

Uneven-aged virgin forests in which, on the average, 70 per cent of the trees are mature and overmature are the predominant forest con-

[1] Various statistics in this chapter are taken from several issues of "Forest Research Notes" and other mimeographed publications of the Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

[2] Detailed data for Idaho are not available.

dition. Occasional trees are 600 years old, but most of the older trees are 250 to 300 years. Poles and saplings, generally in even-aged groups, are scarce. In southern Oregon these stands average 12,000 to 18,000 board feet per acre over extensive areas, and 20,000 to 30,000 board feet per acre on small tracts (Fig. 89). Elsewhere the stands

Photograph by U. S. Forest Service.

Fig. 89. A virgin stand of ponderosa pine typical of the better sites in central Oregon. Reproduction, although present in considerable quantity, is suppressed by snowbrush (*Ceanothus velutinus*) in foreground.

have small volumes, 10,000 to 15,000 board feet per acre over large areas, but varying from 6000 to 25,000 board feet per acre.

Even-aged second-growth forests occupy less than 1,000,000 acres. Selectively cut forests differ from the virgin forests mainly in their smaller proportion of overmature and mature trees. Clearcut land comprises approximately 1,000,000 acres, some of it severely burned and supporting little or no forest growth; but a larger area is unburned and, on the average, 50 per cent stocked with seedlings, saplings, and poles.

Stand Regeneration and Development. *Advance Reproduction.* Some advance reproduction, mostly under 1 foot tall, is present in old-growth forests, its abundance, distribution, and size apparently being related to past fire history, density of stand, and character of ground cover (Fig. 89). Reproduction is most abundant in mixed stands, other conditions being comparable, especially where white firs are present. A considerable amount of young growth is destroyed in logging—usually 2 to 58 per cent of the trees under 2 feet tall and 3 to 82 per cent of the trees between 2 and 5 feet tall (Mowat 1940, Perry 1929).

Subsequent Reproduction. Ponderosa pine bears heavy seed crops at intervals of 3 to 5 years and may or may not bear small amounts of seed during the intervening years. When the crop is light, part of the seed is rendered worthless by cone weevils, and some of it is consumed by chipmunks and squirrels, leaving little viable seed. Trees must be at least 16 inches d.b.h. and often 20 inches d.b.h. before they are effective seed producers. The seed matures in late August or early September and most of it is promptly disseminated within 2 weeks.[3] It germinates the following spring, there being no evidence that some of it lies dormant in the soil until the second year.

Seedlings seldom become established in large numbers during a single year, owing to severe summer drought and frosts (Weidman 1936).

A full stand of seedlings must usually come gradually over a period of 20 to 25 years.

Certain factors that can be controlled influence regeneration, but present evidence indicates that climatic factors are the greatest retardant to prompt abundant reproduction. Adequate soil moisture in late summer is especially important to the survival of 1- and 2-year seedlings. On pumice soils frost heaving is an important cause of seedling mortality (Munger 1917).

Certain types of vegetation, such as snowbrush, manzanita, and squaw carpet, especially when of moderate density, favor seedling establishment (Munger 1917, Sproat 1930) (Fig. 91), probably by conserving moisture as does slash (Munger and Westveld 1931).

Chipmunks play a dual role in ponderosa pine regeneration: burying seeds, several in a spot, from which the "rosettes" of reproduction apparently originate, and feeding on, and thereby destroying, numerous seedlings, especially the first-year seedlings. Livestock interferes with regeneration on overgrazed areas.

[3] The heaviest fall of seed released 150 feet above ground in a wind having a velocity of 3.5 miles per hour was at 300 feet from the point of release (Isaac 1930).

Wherever lodgepole pine is a component of the stand, it reproduces well on a recently burned surface and, because of its aggressiveness, exerts considerable influence on the entire reproduction stand (Munger 1914). Lodgepole pine (Korstian and Baker 1922), as well as western larch, seedlings grow rapidly but, inasmuch as they are very intolerant, ponderosa pine seedlings do not suffer seriously from the competition of these elements. Other associated species do not enter conspicuously into the regeneration picture on dry ponderosa pine sites. On moist sites, however, the tolerant species, firs and cedars, have a significant influence on the reproduction of the stand. Their presence as advance reproduction gives them an immediate advantage, accentuated by their high degree of tolerance, which makes them strong competitors. Under natural competition they hold their own or are likely to gain numerically.

Stand Development. Ponderosa pine seems to be fairly tolerant as a seedling, but as it passes into the sapling and later stages it demands space. Growth becomes very slow in dense stands. At 40 years of age trees in a stand with 14,800 stems per acre had an average diameter of 1.7 inches, whereas trees in an adjacent stand, thinned at an early age by fire and having 1100 stems per acre at 40 years, had an average diameter of 7.4 inches (Weaver 1947). The growth of the reproduction stand is influenced greatly by the density of the reserve stand. Conversely, the growth of the reserve stand is influenced by the density and size of reproduction and young growth, as well as by other factors noted below (Meyer 1934).

Growth of individual trees in the reserve stand depends on the uncontrollable factors, site quality and growth cycles, and such partially controllable factors as tree class, spacing, and amount of release. Keen's tree classes, which were developed originally as a basis for determining susceptibility of ponderosa pine to attack by the western pine beetle, are useful in evaluating growth differences in ponderosa pine trees. These tree classes, based on site IV conditions, are described in Tables 33 and 34 and illustrated in Fig. 90 (Keen 1943).

The effect of age and vigor on growth is shown in Table 35 in which Keen's age and vigor classes are used (Briegleb 1943).

The growth of the stand as a whole is influenced by the individuals that comprise the stand, as well as by the make-up of the stand with particular reference to volume, composition, and structure of the reserve stand. In age classes 1 and 2 all except vigor class *D* trees make average or better than average growth; in age class 3 only vigor classes

A and *B* produce average or better than average growth, whereas none of the age class 4 trees meet this standard.

TABLE 33

THE CHARACTERISTICS OF KEEN'S AGE GROUPS FOR PONDEROSA PINE

Age Classes	General Age	Age, years	D.b.h.	Height	Bark	Tops	Branches
1	Young	Usually less than 80 years	Rarely over 20 inches	In lower crown canopy; usually less than 60 per cent of total mature height	Dark grayish brown to black; rough, deeply furrowed without plates, but with narrow ridges between the fissures (sometimes coloring at extreme base)	Usually pointed, with distinct nodes	Upturned and in whorls for upper three-fourths of crown; small for diameter o bole
2	Immature	Approximately 80 to 180 years	Rarely over 30 inches	Usually less than 90 per cent of total height at maturity. Trees still under the general crown canopy	Dark reddish brown with narrow, smooth plates, between the fissures on lower half of bole; dark, rough bark on upper half	Usually pointed, sometimes rounded, but with whorls indistinct	Mostly upturned and in whorls for upper half of crown, horizontal near middle, horizontal or drooping below; small to medium for diameter of bole
3	Mature	Approximately 180 to 300 years	Rarely over 40 inches	Practically that of general crown canopy, except intermediate, suppressed or top-killed trees	Light reddish brown with moderately large plates between fissures on lower three-fourths of bole; dark bark showing in upper quarter	Usually pyramidal or rounded, occasionally pointed; whorls indistinct except at extreme tip	Upturned near top, middle crown horizontal, lower ones drooping; moderately large for size of bole
4	Overmature	More than 300 years	Wide latitude in diameters, but usually large in dominant trees	Full height of general crown canopy, except suppressed, spike-topped or broken trees	Light yellow, and uniform for entire bole, except in extreme top; plates usually very wide, long, and smooth; fissures often rather shallow	Usually flat; occasionally rounded or irregular	Large, heavy, and mostly gnarled or crooked; mostly drooping except in extreme top

Windfall. Severe damage from windfall is not uncommon in either virgin or cut-over stands, but it is localized. The danger of damage is greatest during the first 6 years after cutting when the wind velocity

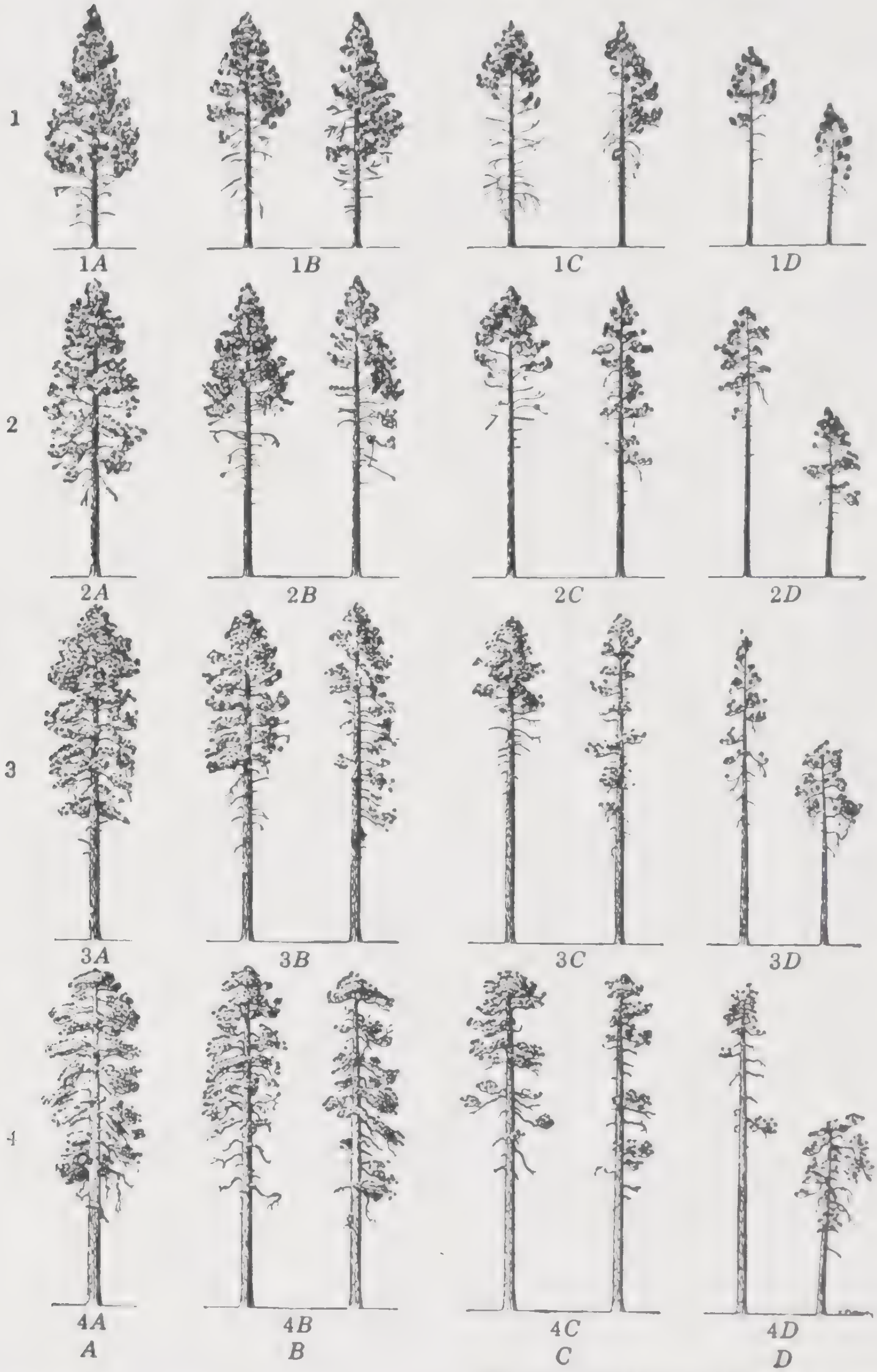
reaches 30 miles or more per hour, when as much as 17.5 per cent of the merchantable volume of the reserve stand has been windthrown, and loss may reach 25 per cent (Weidman 1920*a*, 1920*b*). There is

TABLE 34

THE CHARACTERISTICS OF KEEN'S CROWN-VIGOR CLASSES FOR PONDEROSA PINE

Crown-Vigor Class	General Vigor	Crown Size	Foliage	Position	D.b.h.
A	Full vigor	Full vigorous crown with a length of 55 per cent or more of the total height, and of average width or wider; with density average or better, for its age class	Needles of average length or longer, usually dense and thrifty	Usually isolated or dominant, rarely codominant	Large for age
B	Good to fair	Good to moderately vigorous crowns with length from 30 to 55 per cent of total height, if of average width and density; or a longer crown, if narrow or somewhat thin; but neither sparse nor ragged	Needles of average length, usually dense and thrifty	Usually codominant, but sometimes isolated or dominant; rarely intermediate	Average or above for age
C	Fair to poor	Fair to poor crowns, with length 10 to 30 per cent of total height, if of average width and density or long, sparse, and narrow; often flat on one or more sides	Needles often short and thinly distributed, but of normal length and density when confined to top one-third of crown	Usually intermediate, sometimes codominant or suppressed, but rarely isolated	Usually below average for age; sometimes large in decadent trees
D	Very poor	Very short, less than 10 per cent of the total height; sometimes merely a tuft at top of tree, or somewhat longer when sparse and ragged; usually very narrow or limbs all on one side	Needles often short, and foliage sparse or scattered, or only tufts at end of twigs; but of normal length and density if reduced in quantity	Usually suppressed or intermediate, but may occupy other position if greatly reduced in vigor	Decidedly subnormal for age, but very old decadent trees may be of large diameter

some evidence that windfall is greatest in large groups of trees (Smith and Weitknecht 1915), and trees from such groups isolated by cutting are especially susceptible. It has been suggested recently that light reserve stands suffer the greatest windfall loss and that, on the basis of individual trees, the best full-crowned trees are the most susceptible.



Photograph by U. S. Forest Service.

FIG. 90. Keen's sixteen tree classes for ponderosa pine based on age (1 to 4) and vigor (*A* to *D*).

TABLE 35

NORMAL 10-YEAR GROWTH IN DIAMETER AT BREAST HEIGHT, OUTSIDE BARK, BY TREE CLASS *

Age Class	Vigor Class *A*	*B*	*C*	*D*	Unweighted Average
	Diameter Growth, inches				
1	1.56	1.21	0.92	0.66	1.09
2	1.21	0.97	0.71	0.49	0.84
3	0.90	0.71	0.50	0.37	0.62
4	0.55	0.46	0.37	0.27	0.41
Unweighted average	1.06	0.84	0.62	0.45	0.71

* The values shown above and to the left of the line are above the unweighted average of all tree classes combined.

ECONOMIC BASIS

Utilization and Marketing Problems. Over extensive areas the question of relative value of species has no bearing on the silviculture of the ponderosa pine type because only one species—ponderosa pine—is represented. In any case ponderosa pine is the most valuable species, but other species have sufficient value to justify their utilization. Sugar pine, although yielding excellent lumber in California, often produces inferior lumber in southern Oregon and is therefore generally not so valuable as ponderosa pine. Lodgepole pine is most valuable where it can be used for cross-ties. Douglas-fir is a second-rate wood, although employed to some extent for lumber and cross-ties. The demand for the lumber of white firs is weak. Other species, more sparingly distributed, are generally utilized reasonably well.

Trees that do not yield saw logs cannot be utilized profitably, the demand for fuelwood and other small products being satisfied from sawmill waste, the larger pieces of slash, and cull logs left on cut-over land. Even the smaller saw-log trees cannot be utilized advantageously; a tree must be 16 to 19 inches d.b.h.[4] to yield a profit from the lumbering and sawmilling process (Gibbons, Johnson, and Spelman 1930). It is only on trees about 22 inches d.b.h. and larger that the margin for stumpage and profit is reasonably large. Of particular

[4] The range is somewhat wider as indicated by certain unpublished data, and varies from tract to tract, from mill to mill, and from year to year.

significance are the findings of recent years which demonstrate that the margin of profit on the large high-quality trees is so much greater than that on small low-quality trees that a light cut of high-quality lumber can easily carry the increased cost of logging incurred by the light cut. Tractors and trucks, which have given flexibility to logging, and low, fixed per acre costs are responsible for this condition.

TABLE 36

BOARD-FOOT VOLUME GROWTH, SCRIBNER RULE, IN SELECTIVELY CUT STANDS OF PONDEROSA PINE OF AVERAGE STRUCTURE, SITE QUALITY IV

Volume per Acre of Reserve Stand				Average Annual Increase in Volume per Acre for 60-Year Cycle	
At Time of Cutting	After an Interval of				
	10 Years	40 Years	60 Years		
Board Feet	Board Feet	Board Feet	Board Feet	Board Feet	Per Cent
1,000	1,400	2,800	3,600	43.3	4.33
5,000	6,000	8,700	10,200	86.7	1.73
10,000	11,300	15,300	17,500	125.0	1.25
15,000	16,500	22,100	25,100	168.3	1.12

Growth and Rotation. The volume of the reserve stand, among other things (see p. 507), influences the rate of growth of a stand. Growth in percentage increases as the volume of the reserve stand decreases, but growth in board-foot volume increases as the volume of the reserve stand increases, as shown in Table 36 (Meyer 1934). These data do not give a complete picture of the growth on an entire tract, which, from the management standpoint, is very important. For a whole timber tract the difference in total growth is greater than that indicated on a per acre basis, because in the retention of a large reserve stand it is necessary, in order to secure a certain volume of timber from cutting, to cut a larger area each year than when a small reserve stand is retained. More acres of forest, therefore, are converted each year from a stagnant virgin forest with little (Connaughton 1935) or no net growth to a productive cut-over forest. In one case, for each 72 board feet produced by a light reserve stand (3000 board feet),

approximately 200 board feet were produced by a heavy reserve stand (10,000 board feet) (Brandstrom 1937). Although in this case the heavy reserve stand produced three times as much volume increment as the light reserve stand during the first cutting cycle, its value increment is five times as great. The differences will not be so marked in succeeding cutting cycles, but the short cutting cycle always produces the greater growth.

The length of the cutting cycle must vary with the size of the reserve stand, from 20 to 75 years. A rotation of 180 years is needed to produce saw logs on an average site.

Financial Aspects. As previously pointed out in a general way, light cutting (silviculturally the most desirable) yields larger returns than heavy cutting. This is borne out concretely in Idaho where the net return from clearcutting was $30.17 per acre or $1.98 per thousand board feet, and from selection cutting $40.72 per acre or $4.82 per thousand board feet (Anderson 1934). Carried a step farther, a cut of 40 per cent of the merchantable timber (the high-value trees only) produces a net stumpage realization per thousand board feet during the first cutting cycle (29 years) that is nearly twice as high as when 85 per cent of the volume is removed (necessitates a 60-year cutting cycle) (Brandstrom 1937). A detailed analysis of tree values on an experimental plot in Oregon revealed on the basis of 1942 costs and values that the marginal value (difference between the lumber sale value and all costs of logging and milling) of the trees that would be cut in the second, third, fourth, and fifth 20 per cent of the stand volume was 74, 37, 17, and 10 per cent of that of the first 20 per cent of the volume (chiefly classes $4C$ and $4D$ trees). In other words, as the volume removed increases, thus including more and more of the faster-growing and least insect-susceptible trees, the margin of profit per thousand board feet decreases. Other financial advantages of a light cut are: rapid creation of a road system that facilitates fire protection, salvage, insect control, and other operations; laying of a substantial foundation for sustained-yield production.

Application of Methods

Selection Cutting. Old-growth ponderosa pine stands can be handled most effectively by selection cutting. In its application, the local condition of the stand with respect to representation of tree classes, amount and distribution of young growth, and insect hazard, and such economic considerations as logging method and costs, growth capacity, and avail-

able timberland area should be the basis for determining the proportion of the stand that should be cut. Because of the wide variation in conditions, it is necessary to remove from large tracts 40 to 85 per cent [5] of the volume in trees 12 inches and larger (Figs. 91 and 92). From acre to acre the variation in amount removed is even greater.

For large tracts where assurance of sustained-yield operation is vital, a light selection cutting, referred to as the "maturity selection system,"

Photograph by U. S. Forest Service.

Fig. 91. The same stand as in Fig. 89, 20 years after selection cutting, which removed approximately 80 per cent of the volume of the stand 12 inches d.b.h. and over, and slash disposal by piling and burning. Note the saplings that are filling in the openings and the reduction in the shrub cover.

seems to satisfy the silvical and economic objectives best and is therefore recommended for careful consideration (Brandstrom 1937; Munger, Brandstrom, and Kolbe 1936). In its application, 40 to 50 per cent (or less) of the volume of the stand should be removed, the selection of the trees to be cut being based on the following considerations:

1. Cut all positive-value trees that will not survive until the next cut.
2. Cut the trees that show a positive conversion value above the average of the whole stand but a low-value increment.
3. Cut some of the low-value increment trees whose conversion value is below the average of the whole stand, as a measure of stand betterment.

[5] Increased efficiency in logging, which now appears practicable, may reduce the minimum to 10 to 20 per cent.

In the application of relatively light selection cutting, Keen's tree classes usually receive the following treatment: classes 1 and 2, left in the reserve stand unless they are "wolf trees" or in poor thrift; classes 3*A* and 3*B*, usually left, except for trees over 30 inches, which are usually cut; classes 3*C*, 4*A*, and 4*B*, usually cut; classes 3*D*, 4*C*, and 4*D*, always cut.

Photograph by U. S. Forest Service.

FIG. 92. Light cuttings under the selection system (40 per cent of the volume removed from the stand shown here) have been made possible by the extensive use of tractors in logging.

For smaller tracts, where sustained-yield management is impractical or where maximum profits are not essential, heavier cutting under the selection system may, in some cases, be more workable than cutting by the maturity selection system. Such cutting, which should remove 75 to 85 per cent of the volume, would take most of the additional volume from classes 4*A*, 4*B*, and 3*C* but would include some volume from classes 3*A* and 3*B*. When seed trees are needed, they should be selected from classes 3*A* and 3*B*. These tree classes would also be retained in increasing number as the volume of the reserve stand is increased. A reserve stand of not less than 2000 board feet should ordinarily be retained (Weidman 1936).

In any cutting under the selection system, badly defective trees—mistletoe-infected, spike-topped, severely decayed, and lightning-struck

trees—should be removed. Special care must be exercised in the selection of trees on areas where the windfall danger is high. Heavy cutting is advisable on the saddles of ridges and on soggy ground. Unusually tall or top-heavy crowned trees should not be retained, as a precaution against windfall, on any site.

In mixed stands preference in favoring trees should be given to the following species in the order named: ponderosa pine, western larch, and Douglas-fir. White fir, especially the large mature ones, and lodgepole pine should be cut as heavily as is compatible with economic conditions.

Cultural Operations and Planting. To realize the maximum increment on young growth (much of it is making only 10 per cent of normal growth (Meyer 1934)) thinnings must be made. Research has not progressed far enough to give more than superficial suggestions on thinning technic. It is believed that in young stands the release of 80 to 150 well-developed trees per acre has merit. In older stands where trees are large enough to be susceptible to attack by the western pine beetle, thinning is valuable in improving tree vitality and thereby reducing the danger of insect damage.

The million acres of devastated land can be made productive only by planting. The problem of rehabilitating these lands is so complex and there is so little practical background on which to base technic that no recommendations are made here.

Slash Disposal

Slash in Relation to Fire

Many factors determine the degree and the length of life of the slash hazard in cut-over old-growth stands, but the amount of slash (determined chiefly by the amount of timber cut), the condition in which the slash is left, and the natural factors of fire hazard are the most significant. Lopped slash is less hazardous than untreated slash during the first few years, but as decay progresses the situation is reversed because later the progress of decay is faster in untreated slash. With the complete fall of the needles—usually by the end of the third or fourth year—the fire hazard is greatly reduced. Thereafter, the reduction is gradual, the amount of reduction depending on the amount of slash attacked by the western red rot (Munger and Westveld 1931). After 7 to 10 years the slash hazard is very low but is not gone entirely until the fifteenth or twentieth year. Slash in piles or deep windrows is very inflammable at the end of 15 years.

Ecological Effects of Slash

Although the circumstances are not fully understood, slash is an aid to ponderosa pine seedling establishment on some sites. Slash is significant as a source of insect infestation only when, as a result of suspension of cutting, green slash is not continuously available, for *Ips* beetles may then transfer their activities to ponderosa pine trees of reproduction, sapling, or pole size (Division of Forest Insect Investigations 1927). Temporarily these insects may do serious damage, but the attack generally is terminated at the end of the first season, and it is localized.

Economic Considerations

Since slash apparently does not produce undesirable ecological effects, cost incurred for its disposal must be justified on the basis of the value in abating the fire hazard. The method of piling and burning effectively reduces the fire hazard, as evidenced by a loss of only 0.01 per cent of the total area under protection so treated on national forests (Munger and Westveld 1931). The method of partial piling and burning with special protection, at 50 to 60 per cent of the cost of complete piling and burning, is giving satisfactory results in fire-hazard reduction. Cheaper methods are too destructive of forest growth, regardless of their value in reducing the fire hazard, to be considered advisable.

Economy in the disposal of slash by piling and burning has been accomplished by bunching slash in crude piles by special devices attached to a tractor, but it has not been demonstrated that slash piled in this manner can be burned without excessive damage (Colvill 1946, Weaver 1946).

Application of Methods

Slash disposal, to be most effective, should be diversified to take advantage of variable conditions of fire hazard, amount of slash, topography, etc.

The method of piling and burning (or swamper burning) is recommended (1) on small or temporary operations where intensive protection after logging cannot be carried out effectively, (2) on areas of high risk, and (3) on areas where fire lines are likely not to be effective. Elsewhere the method of partial piling and burning with intensive protection is recommended. The extensiveness of the piling and burning must be determined by the intensity of the fire hazard, which is determined in part by the volume of timber per acre cut. Under light

selection cutting (a cut of less than 55 per cent of the merchantable timber), slash should be piled and burned along all permanent and temporary roads and other areas of high hazard. Width of strips on which slash is piled and burned may vary with the degree of fire hazard from 25 to 100 feet on each side of roads. Under heavier cuts, piling and burning should be extended to ridgetops, skid trails, and other strategic points or areas of high hazard.

Disease and Insect Problems

Ecological Basis

Western red rot, a disease that causes much loss of merchantable ponderosa pine in some regions (see pp. 456, 535), is not an important cause of timber loss in the Northwest, only about 2 or 3 per cent of the merchantable timber being destroyed by this disease.

Brown stringy rot infects the white fir at an early age and is the chief cause of defect in this species.

Mistletoe is most common on ponderosa pine growing on poor sites. It attacks lodgepole pine and Douglas-fir to a limited extent. Trees of any species are rarely killed; decreased growth and a depreciation in lumber quality are the usual forms of damage.

The *western pine beetle* is a constant threat to ponderosa pine trees, particularly the less vigorous ones. During epidemics, however, thrifty young trees are attacked and killed (Craighead, Miller, Evenden, and Keen 1931). A combination of circumstances before 1932—a severe drought during 1929 and 1930, followed in April 1931, by a severe windstorm throughout the region—set the stage for the most severe infestation and mortality ever recorded in the region. The windthrown trees were ideal breeding places and the trees weakened by the drought were easy prey for the beetles (Bureau of Entomology 1934). Timber losses of 4, 8, and 15 per cent were common during 1932 [6]—a great increase over the usual annual mortality of 1 to 2 per cent. Although the high mortality of over-wintering broods during the very cold winter of 1932–1933 reduced tree mortality during 1933 to one-half that of the previous year, authorities regard the decreased damage as only temporary and believe that permanent relief can come only after a marked improvement in tree vigor and growth (Bureau of Entomology 1934). Keen (1943) has established good correlation between tree

[6] Losses of 1000 trees per section were usual, and complete destruction of the forest occurred on areas up to 10 acres.

mortality caused by the western pine beetle and his tree classes. Arranged in order of mortality ratio from lowest to highest the sixteen tree classes occur as follows: 1*A*, 2*A*, 1*B*, 3*A*, 4*A*, 2*B*, 1*C*, 2*C*, 3*B*, 1*D*, 4*B*, 2*D*, 3*C*, 3*D*, 4*C*, and 4*D*. It is apparent that trees of lowest vigor (*C* and *D*) are the greatest risks and that young trees (1 and 2) are low risks. Within an age class the mortality ratio increases from vigor class *A* through class *D*.

The *mountain pine beetle* commonly kills individual ponderosa pines, especially where lodgepole pines are in association. Its most aggressive attacks are in immature even-aged stands that are suffering from stagnation. In such stands it frequently kills numerous small groups of trees and has been known to wipe out completely a second-growth pine stand over several hundred acres.

The *pandora moth*, a defoliator, periodically makes its appearance in large numbers (the factors contributing to these outbreaks are not known), as it did from 1918 to 1925 and again in 1933 (Patterson 1929). Some trees that are defoliated for more than one consecutive year may die as a result of the defoliation alone. More often, large areas of defoliated, weakened trees become a fertile field for increased bark-beetle damage.

The *pine butterfly*, which appears to be ever present in ponderosa pine stands feeding lightly on pine foliage during the caterpillar stage, fortunately becomes epidemic only at long intervals. In the few serious outbreaks which have occurred, extremely heavy defoliation has killed large bodies of mature ponderosa pine. In one outbreak on the Yakima Indian Reservation in 1893–1895, practically all the mature pine over six townships was destroyed. In another instance in central Idaho during a 14-year period, 26 per cent of the mature ponderosa pine was killed (Evenden 1940). Vigor is probably a factor in ability of trees to survive defoliation and recover.

Engraver beetles attack trees of pole size or smaller, killing small groups of trees now and then, but seldom becoming serious unless logging slash aids in their propagation (see p. 517). Working in conjunction with the mountain pine beetle and the western pine beetle, engraver beetles may do serious damage.

Economic Basis

Only for the western pine beetle are data on the economic aspects of control available. So many variables enter into the picture of western pine beetle control that the dividends on control operations vary greatly, but in general the results justify the investment. Initial

control costs from \$0.30 to \$1.15 per acre, with subsequent treatments, if needed, costing less. On one project in 1932 an expenditure of \$31,000 saved from destruction by the beetle merchantable timber worth an estimated value of \$63,900,000—certainly a worthwhile undertaking. In another case control operations reduced insect losses 7 per cent, whereas insect losses on an untreated area increased 141 per cent during the same period (Bureau of Entomology 1934).

Control Methods

Control of diseases, none of which cause severe or widespread damage, can be accomplished most effectively by judicious selection of trees in cutting operations (see p. 515).

It is generally agreed that the control of the western pine beetle must be aimed at two different situations—epidemics and endemic infestations. The method of treating epidemics and special conditions that may lead to an epidemic is pretty well standardized. Just how far it is advisable or practical to go in the cutting of old-growth forests to reduce their susceptibility to western pine beetle attacks to the minimum is not known (Brandstrom 1937). Trees in vigor classes *C* and *D* of the two older age classes should be cut heavily, and ordinarily class *D* trees of other age classes also should be removed to reduce the insect hazard. On the other hand, Keen's tree classes 3*A* and 4*A* can be retained in the reserve stand without great risk.

When critical conditions are created, such as by severe windfall, special control measures are necessary. Bucking up, close to the root-collar, each windthrown tree and lopping off the branches are recommended in such cases (Weaver 1934).

Where an epidemic develops, special control measures should be initiated at once. Felling of the infested trees should be done preferably during the fall, winter, or spring months; and, if the logs cannot be utilized, their bark should be removed and burned before the first of June. If utilization of the logs is possible, they should be removed.

Control of Animal and Logging Damage

Too little is known about the relation of grazing to regeneration to recommend any regulatory measures for general application, other than good range management. Where slash is left untreated, however, the number of animals allowed to graze should be reduced for several years, until the slash breaks down enough to make the forage under-

neath it available to livestock. Reduction in number of livestock is advisable also on loose soils (Weidman 1936).

Poisoning of porcupines, as outlined on p. 458, is recommended where these animals do serious damage.

Poisoning of chipmunks may be advisable where they injure or interfere with reproduction, but such control should be used with discretion.

Tractor or horse logging, executed on the basis of a logging plan made in advance of cutting, is recommended as a means of minimizing logging damage (Weidman 1936). One of the most effective means is the use on tractors of drums and short skidding lines. In a study made in Idaho, Mowat (1940) concluded that close supervision is necessary to reduce logging damage, which was high among trees of seedling and pole size where long logs were bunched by tractors and skidded by tractors with Fairlead arches.

LARCH–DOUGLAS-FIR TYPE

The discussion of this forest type will be very brief for the following reasons: (1) there is little concrete information about it; (2) opportunities for effectively utilizing it are very limited; (3) it is similar to and presents the same problems as the same type of the northern Rocky Mountain region (see p. 411).

The larch–Douglas-fir type occurs mainly in the Blue Mountains and Salmon River Mountains and, on a small scale, in the northern Cascades, between altitudes of 4500 and 5000 feet. Its continuity is broken by other forest types, so that individual areas of the type are small, but in the aggregate its area is large.

The chief problem in the larch–Douglas-fir type is utilization. The more abundant, better species—Douglas-fir and western larch—are not so much in demand here as in the northern Rocky Mountain region. Furthermore, low-value species are abundant, generally very defective, and in small demand.

Wherever markets and utilization standards are such that the old-growth larch–Douglas-fir type can be cut by a method that is silviculturally desirable, the forest should be cut in order that its future value and productivity may be increased. Selection cutting that favors ponderosa pine, western larch, and Douglas-fir is recommended. This implies fairly heavy cutting—removing 60 to 80 per cent of the merchantable volume, the firs to be cut to a minimum of 14 inches d.b.h. All trees so defective as to render them unmerchantable—with special

emphasis on the old white firs—must be cut. If the market will not absorb all the white fir trees, sound specimens over 14 inches d.b.h. may be left.

Piling and burning of the slash are recommended for general use, because with trees of all sizes intermingled and with branches extending from the tops to the ground, as they do in this type, fire control is extremely difficult. Partial piling and burning are permissible only where stand conditions are most favorable for the control of fire (Weidman 1936).

LODGEPOLE PINE TYPE

The lodgepole pine type is widely distributed, first, in small to extensive areas on flats, intermingled with the ponderosa pine type at 4000 to 6000 feet, and, second, in an extensive distinct forest zone above the latter at elevations of 5000 to 6500 feet. Over most of its range it is apparently a permanent type, but where it borders other forest types (particularly where it adjoins the ponderosa pine type) it is probably only temporary, having taken possession of these sites after fire (Munger 1914). Over vast areas only one species—lodgepole pine—comprises the stand. Ponderosa pine and Douglas-fir are common associates at the lower elevations; white fir, alpine fir, Engelmann spruce, and western hemlock, at the higher elevations.

Either the lodgepole pine type is too inaccessible or ponderosa pine is too plentiful to develop much demand for the products of the lodgepole pine type. Small tracts of mature timber that are intermingled with the ponderosa pine type can be utilized to best advantage, chiefly for hewn cross-ties used in the construction of logging railroads. Such mature stands should be cut by the shelterwood method (see p. 427). Slash disposal should be the same as in the ponderosa pine type.

SUBALPINE TYPE

The subalpine types occupy the upper zone of forest vegetation at 6500 to 8000 feet. Being very inaccessible, they have no present commercial value, but they are very important for watershed protection. The climax types of mountain hemlock–alpine fir, Engelmann spruce–alpine fir, and white fir (Committee on Western Forest Types 1945) are uneven-aged, with mature and overmature trees predominant, and contain 10,000 to 15,000 board feet per acre. Cutting in these forests is not likely to materialize for another 50 years or more.

WOODLAND TYPE

In some sections of the region the Sierra juniper or Rocky Mountain juniper type forms a zone of forest vegetation below the ponderosa pine type (Committee on Western Forest Types 1945). Occasional ponderosa pines, usually of poor quality, are scattered through many of the stands. The woodland forests are very open, and the vegetation and tree reproduction in them are very sparse. Fence posts and pencil wood are the chief commercial products that can be derived from them. Selection cutting provides the best means of perpetuating the woodland type. Slash disposal is unnecessary.

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16. *Black Hills Ponderosa Pine Region*

DESCRIPTION AND HISTORY

Location and Landownership

The silviculture of the ponderosa pine region of the Black Hills is sometimes discussed in connection with the southwest ponderosa pine region (Pearson and Marsh 1935); but, since the former region is a separate economic unit and because the forest conditions differ from those in the Southwest (see Chapter 13), the Black Hills is treated here as a distinct region. The region is confined to the Black Hills, an isolated mountain range in western South Dakota, southwestern North Dakota, eastern Wyoming and southeastern Montana (Fig. 1). The region occupies a belt approximately 100 miles long and 40 to 50 miles wide with an area of somewhat more than 2,500,000 acres. The net area of the two national forests in the Black Hills is 1,286,759 acres (June 30, 1947).

Privately owned forest is of two classes, the small farm woodlands and the more extensive areas owned by mining companies. Custer State Park in South Dakota with an area of 61,000 acres is the only state-owned forest land of consequence.

Physiographic Features

The Black Hills is the outstanding topographic feature of the region. The topography is extremely diversified. Over extensive areas, especially at the lower altitudes, the topography is gently rolling, the slopes are long and of moderate gradient, and there are no well-defined ridges. In other sections the topography is definitely rugged, as in the vicinity of Harney Peak with an altitude of 7240 feet, the highest point in the region. The hills range from this elevation to 3200 feet. The precipitous slopes characteristic of the box canyons are usually very rocky, frequently covered with insufficient soil, on small areas, to support

tree growth. Many of the higher slopes are characterized by rock slides, some of which are extensive.

The soils of the Black Hills are very fertile, consisting largely of excellent sandy and silty loams. They are derived chiefly from limestone in the western part of the region and chiefly from granite and schist in the eastern part. In the draws and wider canyons the soils are usually deep. At the high elevations and on the steep slopes, they are generally shallow and contain large quantities of stones and boulders.

The Black Hills are cut by numerous streams, all of which eventually flow into the Missouri River. Drainage is chiefly in an easterly direction, except in the western and northern sections of the Black Hills, where drainage is north. Numerous small streams make water available in most sections of the Black Hills.

Climatic Features

The average annual precipitation for most of the Black Hills ranges from 17 to 28 inches (Weather Bureau 1926). The precipitation is fairly well distributed through the year, although during the late spring and early autumn it is rather light. A rainy season during July and August extends over a period of 1 to 2 months. Snow falls frequently during the winter months but seldom remains on the ground all winter. Normally the ground is bare for several weeks during winter. In exceptional years the ground is bare most of the winter.

The relative humidity is high during most of the year. During the growing season it varies from 60 to 80 per cent. In late spring and early fall, the driest seasons, the relative humidity occasionally drops to as low as 30 per cent.

The temperature during the growing season is characterized by a wide diurnal change. The days are warm and the nights cool. The mean temperature for July, the warmest month, is 70° F. The winters are moderately cold, especially so at the higher elevations. The average length of the growing season is between 4 and 5 months.

Electrical storms are usually accompanied by rain. Occasional storms are rainless, and such storms usually start many fires.

Development of Lumbering

Lumbering in the Black Hills began shortly after 1850. Nearly all the early operations supplied the lumber and mine props needed to

develop the gold mines. Because of the sparse population the local demand for lumber and other forest products was not great enough to encourage the development of large operations. Limited quantities of lumber have been shipped to the neighboring agricultural regions. The cut in this region has fluctuated from time to time, but the annual output has never exceeded the limit for sustained-yield operation. In 1899 the annual cut was nearly 32,000,000 board feet; by 1910 it had dropped to slightly over 16,000,000 board feet; and in 1924 it reached its peak of more than 51,000,000 board feet.

Much of the timber cut in the Black Hills ponderosa pine region has been fabricated by small portable or semiportable sawmills. This type of operation fits in well with the character of timber and the extensive system of fairly good roads. A few mills have capacities of 30,000 to 60,000 board feet daily.

Since 1918 the Burlington Railroad, using railroad ties, grain doors, and lumber in considerable quantity, has improved the market for the poorer grades of timber (Webber 1933).

The Effect of Past Practices

Cutting on national forest land, chiefly by the selection method, has been done with the express purpose of leaving the cut-over land in a productive condition and to provide for sustained yield. With the general abundance of reproduction in the Black Hills, such conservative cutting has left cut-over lands well stocked. In farm woodlands, cutting has frequently been done to prepare the land for agriculture. Elsewhere, the forest has been culled of the better trees and frequently used for pasture.

Before organized fire protection a number of very bad forest fires passed through the Black Hills. Extensive areas were left devoid of forest growth. Soon after these forest areas were put under the administration of the Forest Service, an effort was made to restock this denuded land by direct seeding of ponderosa pine, the first work being done in 1905. During the 5 years that the work was carried on, seedling establishment was, in general, poor, owing presumably to drought and wholesale destruction of seed by rodents (Murdock 1913). The well-organized fire-protection system of the Forest Service has been effective in preventing large fires. The method of piling and burning slash has been used with success as a fire-preventive measure on cut-over lands.

An extensive program of thinning sapling and pole ponderosa pine stands was undertaken when the Civilian Conservation Corps program was started. By the end of the program approximately 250,000 acres of sapling and pole stands had been thinned (Stuart and Roeser 1944). A few thousand acres of these stands had been pruned also.

THE FORESTS AND THEIR MANAGEMENT

Forest types other than ponderosa pine occupy a relatively small area. The western white spruce type occurs in narrow strips along stream bottoms and above an altitude of 5500 feet, where it appears as an open patchy forest of little present commercial value. The aspen type, establishing itself temporarily after fire, occurs in small areas.

INTERIOR PONDEROSA PINE TYPE

Cutting and Planting

Ecological Basis

Composition and Character of Forest

Importance.
  Area—Major.
  Commercial Value—High.
Sites Occupied—Any site between 3500 and 5500 feet altitude, except stream bottoms.
Associated Species.
  Major—Ponderosa pine, usually almost pure.
  Minor—Aspen, paper birch, eastern hophornbeam, western white spruce.
Place in Succession—A permanent type.

Most of the virgin forest is uneven-aged, the different age classes occurring as small groups. These stands are open and contain many defective, overmature trees. Less extensive in area are the two-storied forests composed of a dense understory of saplings and poles and an open overstory of mature and overmature trees, many of them fire-scarred. Extensive areas of sapling and pole stands, so dense that growth is stagnant, are intermingled with stands already described.

Light volumes of saw-log trees, 5000 to 8000 board feet per acre, characterize the virgin forests. Occasional stands occupying as much as 40 acres contain 10,000 to 15,000 board feet per acre.

Fires and the Black Hills beetle laid waste a considerable acreage of forest before 1905. Some of this acreage is still devoid of forest growth.

Stand Regeneration and Development. Climate and soil are favorable to the reproduction of ponderosa pine. Except where fire has burned recently and where the virgin forest is dense, advance reproduction is so abundant that its growth stagnates at an early age.

Seedlings soon occupy openings made by cutting if seed trees are near, because good seed crops are produced about every 3 years, and soil and moisture are favorable to reproduction except during the occasional dry year (Smith 1915). Controlling the density of the seedlings is the major problem. Attempts to reduce the number of seedlings by scattering slash have generally given negative results. As the seedlings develop into saplings and finally into poles the mortality is heavy, but it is usually inadequate to promote normal growth. Without treatment these stands yield few saw-log trees at maturity.

Studies of these sapling and pole stands reveal that all trees do not respond to increased space provided by thinning. During a 6- to 7-year period after thinning, trees in the thinned stands between 1 and 6 inches d.b.h. grew slightly faster than trees of the same size in unthinned stands (Stuart and Roeser 1944). Trees in the thinned stands between 8 and 10 inches d.b.h. grew slightly slower than trees of this size in unthinned stands. It may be safe to conclude that the larger trees had been severely crowded so long that their resultant small crowns prevented them from taking advantage of their released condition. Growth might improve as the crowns increase in size.

The growth and development of the reserve stand is dependent on the character of the trees that compose it. Hornibrook (1939*a*) found that growth could be correlated with age and vigor of individual trees. Using a modification of the original Keen tree classes [1] he found the relationships that are shown in Table 37.

Windfall. Except on limestone outcrops, ponderosa pine develops a strong root system unless the trees are too crowded, as is the case in very dense stands. In spite of the restricted root systems in such stands, the trees appear windfirm when the stand is opened by cutting.

[1] Keen redescribed his original tree classes (see p. 508) in 1943. The changes in his descriptions are minor, as are the differences in characteristics which Hornibrook recognized. Therefore, by referring to Keen's revised classification, the reader will find the fundamental characteristics of the classes that Hornibrook recognized.

TABLE 37

DIAMETER GROWTH OF PONDEROSA PINE FOR A 25-YEAR PERIOD AFTER SELECTION CUTTING, BY AGE AND VIGOR CLASSES *

Age Class	Vigor Class			
	A	*B*	*C*	*D*
	Growth, inches			
1	3.01	2.29	1.95	1.02
2	3.01	2.32	1.76	1.23
3	2.46	1.65	1.32	0.94
4	1.44	1.27	0.94	0.70

* The values shown above and to the left of the line are above the unweighted average of all tree classes combined.

ECONOMIC BASIS

Utilization and Marketing Problems. Since low-value species are sparse in the ponderosa pine forests, utilization is relatively simple. Saw-log trees of relatively poor quality can be marketed at a profit because the local demand for wood products is active. Light volume per acre is no obstacle to profitable operation because transportation systems are well developed; therefore, transportation charges are low.

Although a large market for the products that can be obtained from trees of sapling and pole size—fuelwood, fence posts, and telephone poles—has not been developed, there should be a large potential market for some of these products in the adjacent prairie areas. All these products are now taken from the forest in limited quantity.

Growth and Rotation. Growth is slow, being approximately 70 to 80 board feet per acre annually for a site of average quality. A 16-inch tree can be grown on a 140-year rotation (Pearson and Marsh 1935). Although the most effective length of cutting cycle has not been determined, it appears that periodic cuttings that remove about 1000 board feet per acre at 10-year intervals and leave a reserve of 3000 board feet, composed of the most vigorous trees of the younger age classes, give the maximum yield. Hornibrook (1939*b*) has developed a method for predicting future yields of selectively cut stands.

Financial Aspects. Natural reproduction costs practically nothing since seldom is it necessary to adopt special measures to secure it.

Planting is unquestionably the most economical method of artificial regeneration. This is borne out by comparative costs of planting and direct seeding, the expense of the latter operation being prohibitive (Murdock 1913).

Thinning is usually a direct charge against the future crop, since only limited amounts of the material removed can be marketed. Extensive thinning, involving the removal of all but the crop trees, has required, with CCC labor, 2.7 to 4.9 man-days of labor per acre. "Crop-tree" thinning should require at least one-third less labor. The economic justification of such operations, especially in stands with trees over 7 inches d.b.h., may be questioned in the light of the lack of a response in rate of growth of trees above that size (Stuart and Roeser 1944).

Application of Methods

Cutting in old-growth stands must be concerned chiefly with the release of reproduction and the retention of as large a reserve stand—up to 3000 board feet per acre—of silviculturally desirable trees as economic conditions will permit. Rarely is it necessary to make special provision for new reproduction. Partial cutting, generally of the selection type, but in some cases more nearly of the shelterwood type, accomplishes this objective satisfactorily.

Selection Cutting. Selection cutting is best for uneven-aged stands (Fig. 93). Although it is apparently advantageous to retain a reserve stand of 3000 board feet, the volume of the reserve stand that is retained from acre to acre should be determined by structure of the stand by age and vigor classes. Hornibrook (1939*a*) recommends that trees in age class 1 should seldom be cut. Cutting in this age class should be largely a thinning measure that removes trees in vigor classes *C* and *D*. A similar policy should be applied to trees in age class 2. If vigor class *C* and *D* trees of age class 2 must be left, they should be released as much as possible. All trees that are of merchantable size in vigor classes *C* and *D* in age class 3 should be cut. All trees of age class 4 should be cut unless needed for seed, in which case vigor class *A* and *B* trees should be left.

Since the cutting cycle can be short, vigorous trees with minor defects can be retained. When defects severely affect the merchantability of the tree, however, such trees should be cut. Over the limited area where advance reproduction is inadequate, i.e., consists of less than 500 well-distributed saplings, poles, and seedlings over 1 foot high per acre, four seed trees per acre more than 14 inches d.b.h. should

be specifically retained if they normally would not be a part of the reserve stand (Pearson and Marsh 1935).

Cutting in the two-storied old-growth stands has the character of the final removal cutting under the shelterwood system. All the mature and overmature trees, usually few in number, can be removed, thus leaving a reserve stand essentially even-aged. If the understory is

Photograph by U. S. Forest Service.

FIG. 93. Selection cutting in ponderosa pine in the Black Hills should attempt to leave a reserve stand of 3000 board feet of merchantable timber. Slash is usually piled and later burned.

absent over more than one-half acre, seed trees should be retained as previously described.

Thinning. Research does not demonstrate conclusively that the improvement in stands resulting from thinning justifies the high cost. Certainly the methods used in thinning have not caused appreciable increase in growth, and there are indications that the incidence of decay may be increased (see p. 535). Stuart and Roeser (1944) believe that, if thinning is considered advisable, spacing should be closer in stands under 6 inches d.b.h. than previously recommended (Krueger 1936). On that basis, spacing should be as follows (Fig. 94):

1. 5 by 5 feet (1700 trees per acre) in stands averaging 2 to 8 feet high.

2. 7 by 7 feet (890 trees per acre) in stands averaging 8 to 15 feet high.

3. 8½ by 8½ feet (630 trees per acre) in stands averaging 15 to 30 feet high.

In very dense stands composed chiefly of narrow-crowned, thin-foliaged trees over 8 feet tall, closer spacing than the foregoing is

Photograph by U. S. Forest Service.

Fig. 94. A sapling ponderosa pine stand before (background) and after (foreground) thinning to a 6 by 6 foot spacing. The trees are felled in one direction to keep the slash close to the ground.

advisable to lessen the danger of wind damage. In such stands up to 15 feet tall, a 5 by 5 foot spacing, and in stands averaging 15 to 30 feet tall, a 7½ by 7½ foot spacing is recommended. These spacings should be altered to some extent in order that the most desirable trees are retained. Sound, healthy, dominant trees should be the first choice for retention. Where these are inadequate in number sound, healthy codominant trees or dominant trees with minor defects should be left to supplement the former. Trees infested with active broods of Black Hills beetles and those below 8 inches d.b.h. infected with western gall rust should always be cut (Krueger 1936) (see p. 535).

Planting. Planting has little place in the silviculture of the Black Hills; it need be used only as a temporary expedient to restock denuded

areas that are too large to restock naturally in a short time. Choice of species should be confined to ponderosa pine. Spring planting of 3-year transplants (2-1) spaced 8 by 8 feet is recommended.

Slash Disposal

Slash in Relation to Fire

The volume of slash resulting from cutting mature stands is small. On the other hand, the slash volume created by thinning sapling and pole stands is large.

Ponderosa pine slash is highly inflammable during the first 3 years; thereafter, inflammability decreases gradually until at the end of 7 to 10 years it reaches a low point.

In spite of the hazard it creates in thinned stands, the slash in these stands, if it lies close to the ground (within 24 inches), is less risky than that in unthinned stands (Vaughn 1934).

Economic Considerations

Slash disposal in mature stands by complete piling and burning can be done for about 1 man-hour of time per thousand board feet of timber cut. In view of the high values at stake in well-stocked stands, the expenditure seems justified.

The cost of this type of disposal in sapling and pole stands would undoubtedly be much higher, although no data are available to substantiate this statement.

Application of Methods

In saw-log stands all slash should be piled and burned, except on steep slopes and in open stands on south and west exposures, where it should be lopped and scattered (Pearson and Marsh 1935).

In thinned sapling and pole stands partial piling and burning, supplemented by lopping slash that does not lie within 24 inches of the ground, are recommended (Krueger 1934). The piling and burning should be done on 100-foot wide strips on each side of main highways and important secondary roads and on strips 25 feet wide on each side of truck trails. The lopping can be accomplished by cutting the main stem into two or more pieces (Fig. 94, p. 533). If the tops are likely to be utilized for fuelwood in the immediate future, lopping is unnecessary. To make slash disposal even more effective it is advisable to fell away from ridges and trails those trees adjacent to these features, thus leaving a strip approximately 6 feet wide clear of slash.

Disease and Insect Problems

Rots caused by the *red belt fungus,* the *red ring rot,* and the *western red rot,* particularly damaging in mature and overmature trees, result in an average loss of 30 per cent of the volume of the merchantable timber in virgin stands. Young trees are relatively free of rot. Incidence of western red rot in the first log varies directly with age and diameter and inversely with stand density (Andrews and Gill 1941). Infection is worse in large-limbed than in small-limbed trees. Incidence of infection increases rapidly in trees over 80 years old.

Pruning of trees under 6 inches d.b.h. reduces infection. When trees over 6 inches d.b.h. are pruned, only small-limbed trees should be treated.

The *western gall rust* attacks both young and old trees. In severe cases it may impair a tree's growth, but rarely is it the direct cause of a tree's death. Removal of infected trees in cultural operations will aid in improving the health of the stands.

The *Black Hills beetle,* which destroyed nearly 500,000,000 board feet of timber during the epidemic of 1895 to 1904, is present in endemic form in nearly all old-growth ponderosa pine stands. Although it can quickly develop into the epidemic stage, logs, generally available through continuous logging, have apparently absorbed enough of the beetles while in flight to prevent, until 1946, an increase in insect population to the epidemic stage (Craighead, Miller, Evenden, and Keen 1931). A recession in beetle damage did not materialize during 1947. Young as well as mature and overmature trees are being attacked.

The *engraver beetle,* although present in most of the region, rarely does damage as long as cutting is continuous.

Well-regulated cutting is the key to disease and insect control. Careful tree selection as outlined previously will eliminate the trees affected and will leave a stand relatively immune to attack. If thinning is confined to the period October 1 to April 15, the engraver beetle will cause no trouble (Krueger 1936). Epidemic attacks require special control measures not related to silvicultural operations.

Control of Animal and Logging Damage

In view of the lack of evidence that domestic livestock or large game animals are detrimental to tree reproduction, special control measures are unnecessary. Reproduction should be under observation for dam-

age so that overstocking, the chief cause of damage, can be remedied when the occasion demands it.

Control of porcupines by means of a strychnine-salt bait is necessary where destruction by this animal becomes serious.

Although red squirrels have damaged poles by girdling the tops, thus causing the formation of "spike tops" (Pike 1934), the extent of the injury and the complications that might result from control are not well enough known to justify control recommendations.

Because of the character of the ponderosa pine forests and the type of logging usually employed, special precautions in logging are unnecessary.

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17 · *Redwood Region*[1]

DESCRIPTION AND HISTORY

Location and Landownership

The coast redwood region occupies a narrow strip of land averaging less than 15 miles wide, and not over 25 miles wide at any point along the Pacific Coast in California, beginning just north of the Oregon state line at the Chetco River, and extending about 130 miles south of San Francisco Bay (Fig. 1). Important commercial stands of redwood do not extend more than 50 miles south of the Bay. The summit of the outer Coast Range forms part of the east boundary. The original forested area of the region has been estimated most recently to be 1,788,000 acres, of which 600,000 acres were cut over by 1948. Nearly one-fourth of the cut-over land had been put to agricultural use or was denuded, according to 1932 estimates (Show 1932). The virgin stand at that time was estimated at 50,000,000,000 board feet. Except for 60,000 acres in state parks (1948) and approximately 8500 acres in the Six Rivers National Forest, the land is privately owned.

Physiographic Features

The region is mountainous, being made up chiefly of the California Coast Range, consisting of a series of parallel ridges running in a north-south direction. The individual ridges are uniform in altitude, most of them extending from 3000 to 4000 feet above sea level, with occasional peaks reaching a height of 5000 feet. The topography is, in general, rather rough. The slopes are steep and the ridges are intersected by numerous narrow ravines. Level flats occupy narrow strips adjoining the streams.

[1] The author is indebted to Professor Emanuel Fritz for up-to-date statistics and opinions on practices that are not available in published form.

The soil varies from a thin rocky loam on some of the steepest slopes, to a fine, deep silt on the flats and benches. In some parts the clays are close to the surface, and clay loams and sandy clay loams take the place of the more typical loams and silts.

Climatic Features

Moderate and equable temperatures, frequent dense fogs, and strong northwesterly winds characterize the climate of the redwood region.

In general, the precipitation is heavy. Most of the region has an annual precipitation of 40 to 80 inches, with some points getting as much as 100 inches (Weather Bureau 1926). A dry season, beginning in June, becomes especially acute during July and August and usually extends into late September. The dry period may continue into December. Snow in small amount sometimes falls at the higher altitudes.

The relative humidity is high throughout the year, especially near the coast. Occasionally it falls as low as 20 per cent for 3 to 5 days in September and October, when fire hazard becomes very high.

There is a narrow range in temperature from one season to another. At Eureka, California, the difference in mean temperature between summer and winter is less than 10° F., the mean temperature for the summer months being 56° F. and for the winter months 47° F. (Weather Bureau 1926). At the higher elevations, the range in temperature is more pronounced. Temperatures below freezing are not often recorded below an altitude of 1000 feet. High summer temperatures are of short duration.

The growing season is long. The length of time between killing frosts is 10 months along the coast and in the extreme southern part of the region, and 7 months elsewhere.

Electrical storms are rare, and they are usually accompanied by abundant precipitation. Winds are variable but are generally from the south and northwest. The northwest winds often attain a high velocity during the winter season. A maximum of 59 miles per hour has been recorded at Eureka, California, on numerous occasions.

Development of Lumbering

The first timber cutting in the redwood region occurred in 1811, when a small quantity of material was cut for building purposes by a Russian colony about 100 miles north of San Francisco. Not until

about 1850 did systematic and uninterrupted cutting begin (Forest Service 1903). The peak of redwood lumber production was reached in 1906, when 660,000,000 board feet of lumber were cut (Forest Service 1927), but the peak production of all species occurred in 1927—704,000,000 board feet. From 1940 to 1947 the total lumber cut was between about 400,000,000 and 640,000,000 board feet per year, of which 70 to 90 per cent was redwood. A relatively few mills produce a large proportion of the lumber.

Effect of Past Practices

The early logging from 1850 to 1890—executed mostly by animals—was a heavy selection cutting that left numerous large trees for reseeding the cut-over land. The seed supply was supplemented by trees in adjacent uncut stands. Most of the well-stocked second-growth stands contain remnants of the original stand. Even as late as 1916, after which high-lead logging rapidly replaced ground-lead logging, a scattering of trees that functioned as seed trees was left after cutting and served to reproduce partially most cut-over land (Person 1937).

Since 1916 timberlands have been clearcut. Clearcutting has usually been followed by broadcast burning of the slash before, and again after, the removal of the logs. Since timber was seldom left standing adjacent to cut-over lands for more than a few years, seeding from the sides was rarely sufficient to provide good natural restocking. Even where reproduction did become established, fire usually wiped out all except a fragmentary stand of young growth. Since redwood coppices fairly well even at an old age, a partial stand of reproduction usually followed such cutting and slash disposal. Burning stimulates the establishment of a heavy cover of shrubs, which is inimical to the establishment of additional reproduction. By 1922 there were 250,000 acres of poorly stocked cut-over land, little of which could reproduce naturally (Person 1937). A survey of 100,000 acres in Humboldt and Mendocino counties showed average stocking of 22 and 34 per cent respectively in the two counties (Person and Hallin 1942).

Forest planting of cut-over land, begun in 1922 and continued on an increasing scale for several years, was discontinued in 1931 because of poor success and business depression. When planting methods that will assure successful survival are developed, planting may be resumed on old cut-over and new clearcut areas. Approximately 26,400 acres of cut-over and denuded land were planted (Person 1937). Much cut-over land still remains only partially productive.

THE FORESTS AND THEIR MANAGEMENT

Although forest types other than the redwood type occur in this region, they do not have sufficient commercial value under present conditions to encourage their exploitation. Discussion is, therefore, limited to this one type.

THE REDWOOD TYPE

Cutting and Planting

ECOLOGICAL BASIS

Composition and Character of Forest

Importance.
  Area—Major.
  Commercial Value—High.
Sites Occupied—All moist sites from sea level to 2500 feet.
Associated Species—Stands must contain over 20 per cent of redwood in the dominant and codominant crown classes to classify as a redwood type (Committee on Western Forest Types 1945).
  Major—Redwood, pure on small areas on the valley flats. Douglas-fir most important associate of redwood. Western hemlock and oaks, particularly tanoak.
  Minor—Western redcedar, California laurel, grand fir.
Place in Succession—Climax type.

Virgin redwood forests are unique for their huge trees and large volumes per acre. Trees 15 feet d.b.h. and more than 300 feet tall are scattered through the forests on the best sites (Fig. 95). Individual acres are reported to support as much as 1,000,000 board feet. Over extensive areas virgin stands contain 90,000 to 100,000 board feet per acre (Show 1932). These forests are always uneven-aged, individual trees differing in age by several hundred years (Forest Service 1903, Fritz 1929*a*). The forest floor supports little vegetation in the denser stands on the flats, in sharp contrast to the abundant and diversified vegetative cover in the most open stands occupying the slopes.

Well-stocked second-growth forests, generally characterized by a high proportion of redwood, occupy more than 400,000 acres.

Much of the recently cut-over redwood land supports scattered redwood sprout clumps seldom stocking as much as 15 per cent of the land, a small number of seedlings of the original species, a moderate

to dense cover of shrubs, and possibly an occasional tree spared in cutting. The amount of seedling reproduction and other vegetation varies with the fire history of the area; recurring fires increase the shrub cover and decrease the quantity of tree seedlings.

Stand Regeneration and Development. Advance reproduction is sparse in virgin as well as second-growth forests, occurring only in openings where the mineral soil has been exposed.

Photograph by U. S. Forest Service.

FIG. 95. The interior of a heavy stand of redwood. Advance reproduction is sparse, and the vegetative cover is dense and diversified.

Redwood Sprouts. Sprouting of redwood and tanoak provides a new stand, on the average less than 15 per cent of full stocking, after the cutting of the virgin forest (Fig. 96). In one instance redwood sprouts provided a stocking of 7.8 per cent (Person and Hallin 1942). Higher densities can probably be expected from the cutting of second-growth stands. Old age does not appear to impair the sprouting ability of redwood except in the northern counties.

Seedling Reproduction. Seed production of redwood and its associates is sufficiently frequent and abundant so that it presents no serious difficulty in regeneration, but low viability of redwood seed (Metcalf 1924) and high mortality of small redwood seedlings indicate that a large seed supply must be provided on cut-over lands to secure adequate

reproduction. Considering that dissemination of redwood seed from cutting edges varies from 200 feet uphill to 400 feet downhill, it appears that for the broken topography characteristic of most of the region four trees per acre on favorable north slopes and eight or more trees per acre on south slopes are essential to an effective stocking of redwood seedlings, i.e., 70 per cent or more of full stocking (Figs. 97 and 98). North slopes reproduce naturally more readily than south slopes,

Photograph by U. S. Forest Service.

Fig. 96. The sprout clumps of redwood furnish a stocking of less than 15 per cent on the average. Where there is no adjacent timber to provide seed, planting is the only method of securing a fully stocked stand.

and planted trees have shown the best survival and growth on north slopes (Person 1937). An exposed mineral soil is essential to good regeneration; consequently, slash burning stimulates reproduction (see p. 548). Seedlings of the tree species associated with redwood react much the same as the redwood, except that they reproduce with less difficulty on sites adverse to redwood, this being particularly true of Douglas-fir.

Inasmuch as the partial shade from shrubs is beneficial to the establishment of seedlings, it may be concluded with safety that a partially cut forest should provide a more favorable site for reproduction than should a clearcut forest. Grass and herbaceous plants, especially the low herbs, are an impediment to natural regeneration, seedling establishment failing completely where such vegetation is dense. Both nat-

Photograph by U. S. Forest Service.

Fig. 97. Clearcutting of the virgin redwood forest, followed by broadcast burning of the slash, leaves little or no tree growth on the cut-over land. If the adjacent stand is not cut too soon, some reproduction will seed in along the edge of the timber.

Photograph by U. S. Forest Service.

Fig. 98. In 7 years a well-stocked stand of seedling reproduction has become established from seed produced by the seed trees and, with the sprout clumps, furnishes a fully stocked stand.

ural and artificial reproduction have a low survival on old cut-over lands supporting a heavy cover of vegetation. Survival of planted trees on south slopes has been particularly low (Schofield 1929).

Rodents and livestock are the cause of heavy seedling mortality on certain sites (see p. 550).

Growth and Development of Reproduction. The rapid growth of redwood sprouts, averaging 2 to 3 feet annually and occasionally as much as 7 feet in a single season (Fritz 1929*b*), is an important factor in the successful domination of redwood on shrub-covered areas. Redwood seedlings do not grow so rapidly but are sufficiently tolerant to compete successfully with their associates. On deteriorated sites, planted redwood seedlings may be exceeded in growth by planted stock of its associates (Person 1937).

Windfall. The root systems of redwood and its associates are sufficiently deep to give sufficient anchorage to withstand strong winds. Windfall is a minor factor. Grand fir is susceptible to windbreakage when exposed. Among other species severely fire-scarred specimens suffer from windbreakage.

Economic Basis

Utilization and Marketing Problems. The large size of the timber in the old-growth redwood forests fostered the use of power yarders (both slack-line and high-lead). It was assumed that the timber could be logged most effectively and cheaply by this equipment. However, because the equipment was likely to destroy most of the trees that might be left standing, clearcutting was inevitable. The introduction of tractor logging in the thirties revolutionized the logging and utilization problem. During the early years of this method, yarding costs were approximately \$0.50 per thousand board feet less with tractor than with donkey logging.[2] If certain more or less intangible factors were included, the difference might be as much as \$1.35 to \$1.70 per thousand board feet in favor of tractor logging (Hallin 1936). Although no later data are available, the increased efficiency developed by more than 15 years of tractor use probably widened the advantage of the tractor over the donkey. Road gradients and log volumes must be carefully regulated to gain greatest efficiency.

During the early efforts with tractor logging, size of the marginal tree was 34 inches in diameter, 20 feet from the base. No new data

[2] These and other data in this section are taken from *Forest Research Notes* 15, 16, and 17, published by the California Forest and Range Experiment Station, Berkeley, California.

to substantiate a lower diameter have been reported, but increased logging efficiency undoubtedly has diminished the size of the marginal tree.

Redwood is the most valuable species, but good-quality Douglas-fir often commands only a slightly lower price. The profitableness of utilizing grand fir fluctuates with economic conditions. Under unfavorable conditions profit in its utilization is uncertain.

Tanoak, formerly employed solely for its bark, is seldom used when it grows in mixture with redwood.

Growth and Rotation. Redwood grows rapidly, trees on the best sites attaining 8 inches d.b.h. in 20 years, and 18 inches d.b.h. in 50 years (Barnes 1925) (Fig. 99). Growth rate decreases somewhat after 50 years (Bruce 1923), but enhancement in value through improved quality continues for several decades.

Second-growth trees under 70 to 80 years ordinarily cannot be utilized advantageously. There is some prospect, however, that a pole market may develop for such material.

Redwood sites have the capacity to produce enormous volumes of timber. This is indicated by a 20-year record on a sample plot on site I which produced a growth of 21,400 board feet, International rule, on five residual trees in 20 years and had a total marketable volume of 208,000 board feet at 85 years (Fritz 1945).

Old redwood trees left in residual stands make satisfactory growth. Fritz (1938) reports a growth rate of 5 to 6 per cent on reserve stands, whereas Person (1942) reports a more conservative growth of 3.18 per cent over a 20-year period as compared to a growth rate of 0.68 per cent prior to cutting. The latter found that the increase in growth after cutting was less for large-diameter than for small-diameter trees. Fritz (1938) states that, by leaving 25 per cent of the volume of the stand in the first cut, a second cut of 25,000 to 40,000 board feet would be possible in 25 years.

Up to an age of 50 years, Douglas-fir, sitka spruce, and grand fir grow as fast as, or faster than, redwood of seedling origin.

Financial Aspects. The size of the marginal tree (p. 544) gives a clue to the financial advantage of partial cutting over clearcutting. To illustrate, it was found in a limited study of one operation that the maximum margin per acre for stumpage and profit ($1082) was realized when all trees 35 inches and larger in diameter were cut; that the maximum profit per acre ($631) was attained when all trees 40 inches and larger in diameter were cut, although there was little range ($616 to $631) between cuts that removed all trees down to diameters of

30 to 50 inches; that the maximum net return per thousand board feet, exclusive of stumpage for the entire tract, was realized by cutting all

Photograph by U. S. Forest Service.

FIG. 99. Many sprouts often develop from redwood stumps. They grow rapidly and will be large enough for utilization in 40 to 50 years.

trees 70 inches and larger in diameter. These values can be taken only as indicators of relative values, since they are based on only one sample plot and one set of selling prices (1936).

Partial cutting has the advantage of increasing the chance for successful regeneration, the cost of which would be inconsequential. In view of the unsatisfactory results in planting—only 32 to 41 per cent of the trees survived in extensive plantings—at an average cost of $8.86 [3] per acre (Person 1937), the economy of natural regeneration is apparent.

Application of Methods

Superior regeneration, ability of released trees of all ages to make excellent growth, and economy in utilization under selection cutting give this method advantages that other methods cannot yield. The fragmentary factual data on these relationships are augmented by years of observations by Professor Fritz, who is convinced that selection cutting is the only method that can be successful silviculturally. Seed-tree cutting can be expected to prove reasonably successful if seed trees are retained in adequate number, whereas clearcutting cannot produce satisfactory results.

Selection Cutting. Selection cutting can be applied with tractor or high-lead logging, but, if the latter system is employed, the lines must not be tight-lined from one tail block to another, and long chokers should be used to reach trees to the side of the logging trail. Moderately heavy cutting should be applied in either old-growth or second-growth stands in order to comply with the requirements for regeneration. A diameter limit of 30 to 50 inches and recognition of the importance of log grade for the individual tree should make it possible to develop a plan of selection cutting that will be profitable as well as successful silviculturally. Maintenance of the mixed character of the forest should be a major objective of the cutting. Trees that are retained in the reserve stand should be free of serious butt defects, should have good healthy crowns, and should have trunks that are clear of branches or stubs for three or four logs (Fritz 1938). Enough volume should be left in the reserve stand to insure availability of approximately 25,000 board feet for cutting in 25 years.

Seed-Tree Cutting. If seed-tree cutting is applied, eight to ten seed trees per acre should be retained. Fewer trees furnish adequate seed for regeneration, but they do not provide sufficient cover for good survival of reproduction. Although choice of species for seed trees is not vital on the more moist sites, it is important on dry sites, where

[3] By spending $2.00 to $3.00 per acre more for the best type of planting stock and increased care in planting, better survival—65 per cent or more—is attainable (Person 1937).

Douglas-fir should be given preference. In the actual selection of seed trees the general thrift and abundance of associated species should be used as a basis for their retention.

Soundness and windfirmness should be primary considerations in the selection of seed trees. On areas of higher than average windfall danger the seed trees should be left in groups. Where slackline yarding is employed, the seed trees must be left at the edges of the setting.

Planting. Planting has a definite place in the silviculture of old cut-over lands, but it should not be attempted until research reveals practical methods of controlling rodents and opening up the vegetation by power equipment (Person 1937). For lands to be cut, planting should not be regarded as a primary means of regeneration, even though it can be accomplished satisfactorily at a moderate cost if done immediately after cutting. On the other hand, planting has merit as a means of supplementing natural reproduction, especially if the site does not become occupied by dense vegetation. In general, it seems best to use transplant stock (1-1) of redwood. Two-year seedlings of other species are suggested. The use of Douglas-fir on the dry sites and sitka spruce and Port Orford white-cedar on the wetter sites, to form mixtures with redwood, is recommended. Planting should be done during the rainy season of December and January. Spacing should approximate 6 by 6 feet.

Professor Fritz, on the basis of 10 years of experiments, results of which have not been published, is convinced that direct seeding has possibilities as a method of regeneration.

Slash Disposal

The volume of slash created by clearcutting or seed-tree cutting is large. Partial cutting produces less slash which, because of its protection by the stand, is less inflammable. Redwood bark, commonly stripped from the logs before they are yarded, adds greatly to the slash volume and fire hazard; it is quite inflammable. During periods of low humidity, which are short, the slash constitutes a high fire hazard; at other times, a moderate one. The slash decomposes slowly, some of it being partially intact and more or less inflammable after 20 years.

Reproduction of redwood is favored by slash burning. Seedlings were eight to ten times as abundant on medium to heavy burns as on unburned or lightly burned areas (Person and Hallin 1942).

Details of slash disposal methods have not been worked out. Some form of burning is indicated to be a silvicultural necessity. Broadcast, spot, and strip burning seem best adapted to meeting the needs of disposal at a moderate cost. Carefully controlled spot burning seems to be the best choice for partially cut stands. Broadcast and strip burning can be used on areas that are clearcut or cut by the seed-tree method.

Slash disposal can be facilitated by attention to the handling of slash during the felling and logging operations. Every effort should be made to prevent the accumulation of slash around the bases of residual trees. A competent person should be responsible for the slash-disposal job. If the following rules are adhered to, the maximum benefits from slash disposal should result:

1. Burn only when weather is safe.
2. Burn in small units preferably 5 acres in size, never over 10 acres (Fritz 1937). Burning should begin on the upper slopes and proceed downhill as the upper areas are safe.
3. Heavy accumulations of slash (and bark) at the foot of gulleys, gulches, and landings should be burned thoroughly.
4. Light accumulations of slash need not be burned.
5. Slash that lies against residual trees should not be burned.
6. After firing an area, a careful check of holdover fires in snags and heaps of unutilized timber should be made and these fires put under control.

Intensive protection should be applied to cut-over lands for several years.

Disease and Insect Problems

Redwood is notably free of serious disease and insect pests. *Brown heart rot* is its chief enemy, accounting for a loss of 12 to 15 per cent of the merchantable volume in virgin timber (Fritz 1931*a*). It enters wounds such as fire scars, broken tops and limbs, and logging injuries. It is rarely found in second-growth stands free of fire wounds, even where a large proportion of the sprouts originate from unsound stumps, thus giving evidence that the disease is not transmitted to the new stand from the old (Fritz 1931*a*, 1931*b*). Effective fire protection and care in logging are essential to reducing losses of merchantable wood from heart rot.

Control of Animal and Logging Damage

Damage to young tree growth by grazing has been observed to be so severe that redwood forest land must be devoted solely to tree growing and be kept free of all types of livestock (Person 1937).

Rodents, principally wood rats, have been such an important factor in the poor survival of planted trees, especially on areas heavily covered with shrubs, that a thorough investigation of this problem, aimed at feasible methods of control, is urgently needed (Person 1937). In the meantime it is unwise to attempt rodent control on a large scale because of the danger of upsetting unduly the biological balance.

Care in felling trees and yarding logs is essential to preventing unnecessary damage in logging. Tractors are recommended wherever partial cutting is attempted. Tractor drivers must be trained to avoid injury to the butts of residual trees.

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18. *Southeastern Alaska*

DESCRIPTION AND HISTORY

Location and Landownership

The forest region known as southeastern Alaska includes a narrow strip of the mainland of southeastern Alaska and numerous islands, several of which have an area of more than 500,000 acres. The area of the region is 22,738,000 acres (Heintzleman 1928). Nearly all the timbered area of the region is in federal ownership. It is estimated that only 1,500,000,000 board feet out of a total of 78,500,000,000 board feet of commercial timber is in private ownership (Heintzleman 1928). Most of the land owned by the Federal Government is included in the Tongass National Forest.

Physiographic Features

Southeastern Alaska is mostly mountainous. The coast range, a rugged mountain mass, extends the entire length of the mainland. The islands are made up of a number of ranges not noticeably different from the coast range, although they are of lower relief and less rugged topography (Heintzleman 1928). The mountains of the mainland are 5000 to 6000 feet in height, with an occasional peak reaching 7000 to 9000 feet. The islands have an elevation of 3000 to 4000 feet. The slopes on both the islands and the mainland are steep and heavily dissected. The shore lines are usually rocky and rise abruptly from the water's edge. Of the many islands that make up a part of this region, sixty-seven of them have an area in excess of 2500 acres each, and seventeen have an area in excess of 50,000 acres each.

For the most part the soils are shallow and contain numerous stones and boulders. Limited areas of new soil are being added to the productive portion of the region by the recession of glaciers. Only along the narrow stream beds does soil accumulate to moderate depths. The

soils seldom dry out, owing to the frequent replenishment of moisture by precipitation. Many of the forest soils are characterized by a thick accumulation of moss or raw humus.

The region has only four large rivers—the Stikine, the Takus, the Alsek, and the Chilkat. Numerous small streams originate in the mountains and usually have swift currents because of the steepness of the topography. With the numerous streams and extensive shore line, the region is well supplied with water resources.

Climatic Features

The climate of the region is characterized by an abundant, well-distributed precipitation, a humid atmosphere, moderate temperatures not subject to extremes, and a moderately long growing season.

There is a wide range in precipitation in different sections. At elevations below 1500 feet, precipitating ranges from an average of 50 to 159 inches per year (Weather Bureau 1926). A large share of the region has an annual precipitation of 80 to 100 inches. The wettest season is from September through November, with a monthly precipitation of 10 to 20 inches. During June and July, the driest months of the year, the precipitation is 3 to 5 inches monthly. At the lower elevations a large proportion of the precipitation occurs as rain. At sea level snow occurs intermittently from October to late April but never accumulates to a great depth. Above 500 feet snow covers the ground throughout the winter and accumulates to great depth by spring. With increased altitude the amount of snowfall increases rapidly. At Juneau, situated at sea level, the annual snowfall is 80 inches, whereas 4 miles distant, at an elevation of 1400 feet, it is 150 inches.

A high relative humidity is characteristic of the entire region. It is very unusual for the relative humidity to fall below 60 per cent (Weather Bureau 1926).

The prevailing south and southwest winds, seldom of high velocity, temper the climate of the region and prevent extremes of temperature. The Japanese current is also an important influencing factor in the climate. The range in the mean monthly temperature for January and July is only 24° to 28° F. (Weather Bureau 1926). The mean temperature for the year along the coast is 40° to 44° F. Below-zero temperatures have been recorded during the winter months, but extremely cold spells are of short duration and infrequent occurrence. The growing season is of moderate length, varying from 4½ to 5½ months.

Thunder storms are infrequent and mild and accompanied by enough rainfall so that they do not constitute a fire hazard.

Development of Lumbering

Lumbering in Alaska is of rather recent origin. The early logging operations were very crude, hand logging frequently being used to get out small bodies of timber near the tidewater (Hoffman 1912). Such crude cutting did not encourage the development of large-scale operations. In recent years, with the development of logging on a somewhat more extensive scale, donkey engines with machine logging have been employed (Heintzleman 1928). In spite of the more efficient methods of logging, cutting has not progressed to a large scale. In 1948, the lumber cut from the national forest was 95,000,000 board feet. This output is less than one-tenth of the estimated 1,000,000,000 board feet of timber that could be cut on a sustained-yield basis. In view of the limited area that has been cut over, almost the entire forested area of the region is virgin forest.

Practically all the timber cutting has been for local consumption. The relatively low quality of much of the timber in southeastern Alaska has been a limiting factor in utilizing the forest. Most of the timber is best suited for pulpwood. In 1927 and again following World War II the paper-pulp industry became interested in the timber resources of Alaska. In August 1948 the U. S. Forest Service entered into its first agreement with a paper company for the sale of 1,500,000,000 cubic feet of pulpwood. The construction of a mill with a capacity of 500 tons of pulp per day is planned.

The Effect of Past Practices

So little cutting has been done in southeastern Alaska that the forest has not been altered noticeably. Those areas that have been cut have usually been exploited for the better-quality trees. Consequently, cut-over land usually supports a fairly good stand of small trees. Western hemlock generally predominates in the stand left after cutting, but owing to the predominance of this species in the understory the Federal Government has followed the policy of leaving seed trees of sitka spruce with the objective of encouraging the regeneration of this species. Slash has not been disposed of, because in this very humid climate the fire hazard of cut-over areas is low. No forest planting has been done.

THE FORESTS AND THEIR MANAGEMENT

Several different forest types occur in southeastern Alaska, but only two, the western hemlock–sitka spruce and the sitka spruce types, have significant commercial value. The others, namely the cedar, "scrub," muskeg, and subalpine types, have their chief value as a protective covering for the soil, rarely being utilized commercially.

Much of the cedar type is classed as a part of the scrub type because it is composed chiefly of stunted poor-quality trees (Heintzleman 1928). On small areas the trees are well develped. Such pieces of forest, if accessible, are utilized for their timber. Western redcedar and/or Alaska yellow-cedar predominate in the cedar type.

The scrub type, occupying poorly drained soils, is made up for the most part of spike-topped defective trees. Cedars predominate, but any, or all, the conifers characteristic of the region may be present (Heintzleman 1928). The type appears to be permanent on poorly drained sites.

The muskeg type, composed of a cover of moss, grass, herbs, and scattered stunted trees, chiefly shore pine, occupies sites of deep peat. It contains no timber of commercial value.

The subalpine type, occurring at altitudes above 1500 feet, is an open forest of stunted poor-quality trees, chiefly mountain hemlock and Alaska yellow-cedar.

THE WESTERN HEMLOCK–SITKA SPRUCE AND SITKA SPRUCE TYPES

Cutting and Planting

Ecological Basis

Composition and Character of Forest. The significant facts about these types are shown in Table 38. Both types occur from tidewater to an altitude of 1500 to 2000 feet. They originate as even-aged forests but ultimately attain the uneven-aged form. The typical western hemlock–sitka spruce forest is composed of an open overstory of overmature hemlock and spruce, 3 to 5 feet in diameter, and an understory of young hemlock, 8 to 24 inches d.b.h. (Kellogg 1910) (Fig. 100). The understory trees are tall, well-formed, clear-boled, and sound (Heintzleman 1928). Such stands have average volumes of 25,000

board feet per acre. Mature forests of western hemlock–sitka spruce, with little or no young forest growth and with individual trees from 30 to 48 inches d.b.h., mostly of excellent quality, are less extensive in area. Average yields of these stands are 30,000 to 40,000 board feet per acre. The thrifty young even-aged stands containing chiefly clean-stemmed, well-formed, sound trees from 12 to 30 inches d.b.h. and yielding an average of 30,000 board feet per acre are the best stands for pulpwood.

TABLE 38

Description of the Western Hemlock–Sitka Spruce and Sitka Spruce Types

Forest Type	Importance		Sites Occupied	Associated Species		Place in Succession
	Area	Commercial Value		Major	Minor	
Western hemlock–sitka spruce	Major	High	Moderate to well-drained soils at low altitudes	Western hemlock Sitka spruce	Western red-cedar Alaska yellow-cedar	Subclimax, succeeded by almost pure hemlock stand
Sitka spruce	Minor *	High	New soils created by retreating glaciers and streams	Sitka spruce	Western hemlock	Temporary, being succeeded by western hemlock–sitka spruce type

* Small blocks rarely over 80 acres in size.

The stands of the sitka spruce type, chiefly young or middle-aged, yield an average of 40,000 board feet per acre, whereas the best stands yield 75,000 board feet.

Stand Regeneration and Development. Advance reproduction of sitka spruce is rarely present, because either the overwood or the understory is ordinarily so dense as to preclude its establishment. Hemlock seedlings, on the other hand, are usually present in considerable numbers.

Western hemlock has several advantages over the sitka spruce in regeneration. Hemlock is a better seed producer and its seedlings are able to become established in new humus, a type of seed bed that is inimical to spruce reproduction (Taylor 1929). Sitka spruce must have a mineral soil and a moderately open site to reproduce success-

fully (Fig. 101). With not less than two sitka spruce seed trees per acre left on cut-over land or with sitka spruce available in adjacent standing timber, a reproduction stand of desirable composition should materialize.

Sitka spruce seedlings compete successfully with seedlings of other tree species of the same age because, after the first 2 or 3 years of

Photograph by U. S. Forest Service.

Fig. 100. A typical virgin stand of the western hemlock–sitka spruce type in Alaska.

slow growth, they grow faster than their associates and soon overcome the early handicap (Hoffman 1912). A moderately heavy overhead canopy apparently impedes the growth of spruce seedlings to the extent that other species dominate the young forest growth.

Maintenance of a mixture apparently is advantageous in that it prevents site deterioration and improves both volume and quality growth of the stand. Spruce alone does not maintain a stand of sufficient density after middle age; hemlock alone maintains a stand of too high density, resulting in stagnation of growth and the development of a thick layer of raw humus.

Windfall. Sitka spruce, western hemlock, western redcedar, and Alaska yellow-cedar, the more abundant species, develop shallow root systems. This, together with the thinness of the soil on many sites, makes the stands fairly susceptible to windfall, particularly if heavy cutting is applied.

Photograph by U. S. Forest Service.

FIG. 101. An excellent stand of reproduction after a seed-tree cutting in the western hemlock–sitka spruce type.

ECONOMIC BASIS

Data on the economics of cutting in southeastern Alaska are lacking; nevertheless, a few facts that bear on the problem are known. Because even the best timber of the region is inferior to that of the Douglas-fir region, where the same species occur, lumber from Alaska could not compete on the open market with lumber from the Douglas-fir region. Since both sitka spruce and western hemlock are satisfactory for pulpwood, the object of timber growing should be pulpwood, not saw logs. For this purpose a rotation of 75 years seems feasible since the mean annual growth culminates at this age (Taylor 1934). When grown in a well-regulated mixture, sitka spruce and western hemlock show little difference in growth rate; therefore, both should be encouraged.

Application of Methods

There appear to be two methods of cutting mature stands that should prove successful, namely, clearcutting and selection cutting. A third method, seed-tree cutting, may have application in special cases.

Cut-over areas must be kept small when clearcutting is practiced, in order that seeding from adjacent stands of timber will be adequate (Fig. 102). If the similarity of conditions in Alaska and the Douglas-

Photograph by U. S. Forest Service.

Fig. 102. Reproduction has come in slowly after clearcutting of the western hemlock–sitka spruce type.

fir region is considered, it seems reasonable that clearcut strips should not exceed one-half mile in width when uncut timber surrounds the cut-over area nor one-quarter mile in width when uncut timber is adjacent to only one side. Clearcutting in stands with a heavy understory of young timber, chiefly western hemlock, will leave a scattered stand, in some places fairly dense. Trees so defective as to be unmerchantable should be girdled, preferably at the time of logging.

Selection cutting is most likely to be successful in the younger stands. The cutting must be fairly heavy if sitka spruce is to reproduce successfully. Cutting to a minimum diameter of 20 inches should ordinarily open the stand enough to accomplish this objective. Because

of the inherent danger of windfall, heavy selection cutting is not applicable to stands of high windfall danger. A second cutting should be feasible in 25 to 30 years.

Although seed-tree cutting has been recommended (Heintzleman 1928), it is of doubtful merit because of the danger of losing the seed trees by windfall before they have served their purpose. On deep soils or in protected situations this form of cutting can probably be used with success, particularly if the seed trees are left in groups.

Planting is at present unnecessary. As logging develops on a more extensive scale, with the attendant disruption of natural forest conditions, artificial regeneration may have to be used to supplement natural regeneration on some areas.

Miscellaneous Silvicultural Problems

Slash, although present in large quantity on cut-over land, is a minor fire hazard because the very humid climate keeps its inflammability low. There is no evidence to indicate that it is either harmful or beneficial to desirable reproduction. In view of these facts, disposal of logging slash is unnecessary, except possibly where heavy accumulations develop, in which event a limited amount of scattering would be advisable.

Decay is rather extensive in old trees. Twelve species of fungi were the cause of most of the rot in a study of sitka spruce, and most of these had gained entrance through tree wounds (Englerth 1947). *Red-brown butt rot* was found most frequently. Wounds caused by porcupines are reported as entrance points for rot in both sitka spruce and western hemlock (Heintzleman 1928). Reduction in porcupine population by poisoning offers a means of combatting rots that enter porcupine wounds. Careful tree selection in cutting and prevention of injury to trees in logging should decrease the amount of decay in stands under management.

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APPENDIX

Common Names of Trees and Their Scientific Equivalents *

Alder, American Speckled	*Alnus incana* var. *glauca* Ait. Loud
Alder, Red	*Alnus rubra* Bong.
Ash, Black	*Fraxinus nigra* Marsh.
Ash, Green	*Fraxinus pennsylvanica lanceolata* (Borkh.) Sarg.
Ash, Oregon	*Fraxinus oregona* Nutt.
Ash, White	*Fraxinus americana* L.
Aspen, Bigtooth	*Populus grandidentata* Michx.
Aspen, Quaking	*Populus tremuloides* Michx.
Baldcypress	*Taxodium distichum* (L.) Rich.
Basswood, American	*Tilia americana* L.
Beech, American	*Fagus grandifolia* Ehrh.
Birch, Gray	*Betula populifolia* Marsh.
Birch, Paper	*Betula papyrifera* Marsh.
Birch, River	*Betula nigra* L.
Birch, Sweet	*Betula lenta* L.
Birch, Yellow	*Betula lutea* Michx.
Boxelder	*Acer negundo* L.
Buckeye, Ohio	*Aesculus glabra* Willd.
Buckeye, Yellow	*Aesculus octandra* Marsh.
Buckthorn, Cascara	*Rhamnus purshiana* DC.
Buckwheat-Tree	*Cliftonia monophylla* (Lam.) Britton
Butternut	*Juglans cinerea* L.
Cherry, Black	*Prunus serotina* Ehrh.
Cherry, Pin	*Prunus pennsylvanica* L. f.
Chestnut, American	*Castanea dentata* (Marsh.) Borkh.
Chinquapin, Alleghany	*Castanea pumila* (L.) Mill.
Coffeetree, Kentucky	*Gymnocladus dioicus* (L.) K. Koch
Cottonwood, Black	*Populus trichocarpa* var. *hastata* (Dode) Henry
Cottonwood, Eastern	*Populus deltoides* Bartr.
Cucumbertree	*Magnolia acuminata* L.
Cyrilla, Swamp	*Cyrilla racemiflora* L.
Dogwood, Flowering	*Cornus florida* L.
Dogwood, Pacific	*Cornus nuttalli* Audubon
Douglas-Fir	*Pseudotsuga taxifolia* (Poir.) Britton

* Based on *Check List of the Native and Naturalized Trees of the United States, Including Alaska,* mimeographed MS by U. S. Forest Service, 1944, and *Manual of Cultivated Trees and Shrubs, Hardy in North America,* 2nd ed., by Alfred Rehder, Macmillan Co., New York, 1940.

Elm, American	*Ulmus americana* L.
Elm, Cedar	*Ulmus crassifolia* Nutt.
Elm, Red	*Ulmus serotina* Sarg.
Elm, Rock	*Ulmus thomasii* Sarg.
Elm, Slippery	*Ulmus fulva* Michx.
Elm, Winged	*Ulmus alata* Michx.
Fir, Alpine	*Abies lasiocarpa* (Hook.) Nutt.
Fir, Balsam	*Abies balsamea* (L.) Mill.
Fir, California Red	*Abies magnifica* A. Murr.
Fir, Corkbark	*Abies lasiocarpa* var. *arizonica* (Merriam) Lemm
Fir, Fraser	*Abies fraseri* (Pursh.) Poir.
Fir, Grand	*Abies grandis* (Dougl.) Lindl.
Fir, Noble	*Abies procera* Rehd.
Fir, Pacific Silver	*Abies amabilis* (Dougl.) Forb.
Fir, Shasta Red	*Abies magnifica* var. *shastensis* Lemm
Fir, White	*Abies concolor* (Gord & Glend.) Hoopes
Hackberry	*Celtis occidentalis* L.
Hawthorn	*Crataegus* spp.
Hazel, Witch	*Hamamelis virginiana* L.
Hemlock, Carolina	*Tsuga caroliniana* Engelm.
Hemlock, Eastern	*Tsuga canadensis* (L.) Carr.
Hemlock, Mountain	*Tsuga mertensiana* (Bong.) Carr.
Hemlock, Western	*Tsuga heterophylla* (Raf.) Sarg.
Hickory, Bitternut	*Carya cordiformis* (Wangenh) K. Koch
Hickory, Mockernut	*Carya tomentosa* Nutt.
Hickory, Nutmeg	*Carya myristicaeformis* (Michx. f.) Nutt.
Hickory, Pignut	*Carya glabra* (Mill.) Sweet.
Hickory, Shagbark	*Carya ovata* (Mill.) K. Koch
Hickory, Shellbark	*Carya laciniosa* (Michx. f.) Loud.
Hickory, Water	*Carya aquatica* (Michx. f.) Nutt.
Holly, American	*Ilex opaca* Ait.
Honeylocust	*Gleditsia triacanthos* L.
Hophornbeam, Eastern	*Ostrya virginiana* (Mill.) K. Koch
Hornbeam, American	*Carpinus caroliniana* Walt.
Incense-Cedar, California	*Libocedrus decurrens* Torr.
Juniper, One-Seeded	*Juniperus monosperma* (Engelm.) Sarg.
Juniper, Rocky Mountain	*Juniperus scopulorum* Sarg.
Juniper, Sierra	*Juniperus occidentalis* Hook.
Juniper, Utah	*Juniperus utahensis* (Engelm.) Lemm.
Larch, Alpine	*Larix lyallii* Parl.
Larch, European	*Larix europaea* DC.
Larch, Japanese	*Larix kaempferi* Sarg.
Larch, Western	*Larix occidentalis* Nutt.
Laurel, California	*Umbellaria californica* (Hook. & Arn.) Nutt.
Loblolly-Bay	*Gordonia lasianthus* (L.) Ellis
Locust, Black	*Robinia pseudoacacia* L.
Magnolia, Fraser	*Magnolia fraseri* Walt.
Magnolia, Southern	*Magnolia grandiflora* L.
Magnolia, Umbrella	*Magnolia tripetala* L.

Maple, Bigleaf	*Acer macrophyllum* Pursh.
Maple, Mountain	*Acer spicatum* Lam.
Maple, Red	*Acer rubrum* L.
Maple, Silver	*Acer saccharinum* L.
Maple, Striped	*Acer pennsylvanicum* L.
Maple, Sugar	*Acer saccharophorum* K. Koch
Mountain-Laurel	*Kalmia latifolia* L.
Mountain-Mahogany, Curlleaf	*Cercocarpus ledifolius* Nutt.
Mulberry, Red	*Morus rubra* L.
Oak, Arizona White	*Quercus arizonica* Sarg.
Oak, Bear	*Quercus ilicifolia* Wangenh.
Oak, Black	*Quercus velutina* Lam.
Oak, Blackjack	*Quercus marilandica* Muenchh.
Oak, Bluejack	*Quercus cinerea* Michx.
Oak, Bur	*Quercus macrocarpa* Michx.
Oak, Chestnut	*Quercus montana* Willd.
Oak, Dwarf Chinquapin	*Quercus prinodes* Willd.
Oak, Emory	*Quercus emoryi* Torr.
Oak, Laurel	*Quercus laurifolia* Michx.
Oak, Live	*Quercus virginiana* Mill.
Oak, Northern Pin	*Quercus ellipsoidalis* E. J. Hill
Oak, Northern Red	*Quercus borealis* Michx.
Oak Nuttall	*Quercus nuttallii* Palmer
Oak, Overcup	*Quercus lyrata* Walt.
Oak, Pin	*Quercus palustris* Muenchh.
Oak, Post	*Quercus stellata* Wangenh.
Oak, Scarlet	*Quercus coccinea* Muenchh.
Oak, Shingle	*Quercus imbricaria* Michx.
Oak, Shumard	*Quercus shumardii* Buckl.
Oak, Southern Red	*Quercus falcata* Michx.
Oak, Swamp Chestnut	*Quercus prinus* L.
Oak, Swamp Red	*Quercus falcata* var. *pagodaefolia* Ell.
Oak, Swamp White	*Quercus bicolor* Willd.
Oak, Turkey	*Quercus laevis* Walt.
Oak, Water	*Quercus nigra* L.
Oak, White	*Quercus alba* L.
Oak, Willow	*Quercus phellos* L.
Palmetto, Cabbage	*Sabal palmetto* (Walt.) Lodd.
Pawpaw	*Asimina triloba* (L.) Dunal
Persimmon	*Diospyros virginiana* L.
Pine, Austrian	*Pinus nigra* Arnold
Pine, Bristlecone	*Pinus aristata* Engelm.
Pine, Digger	*Pinus sabiniana* Dougl.
Pine, Eastern White	*Pinus strobus* L.
Pine, Jack	*Pinus banksiana* Lamb
Pine, Japanese Black	*Pinus thunbergii* Parl.
Pine, Japanese Red	*Pinus densiflora* Sieb. & Zucc.
Pine, Jeffrey	*Pinus jeffreyi* Grev. & Balf.
Pine, Knob-Cone	*Pinus attenuata* Lemm.

Pine, Limber	*Pinus flexilis* James
Pine, Loblolly	*Pinus taeda* L.
Pine, Lodgepole	*Pinus contorta* var. *latifolia* Engelm.
Pine, Longleaf	*Pinus palustris* Mill.
Pine, Pitch	*Pinus rigida* Mill.
Pine, Pond	*Pinus regida* var. *serotina* (Michx.) Loud.
Pine, Ponderosa	*Pinus ponderosa* Laws.
Pine, Red	*Pinus resinosa* Ait.
Pine, Sand	*Pinus clausa* (Engelm.) Vasey
Pine, Scotch	*Pinus sylvestris* L.
Pine, Shore	*Pinus contorta* Dougl.
Pine, Shortleaf	*Pinus echinata* Mill.
Pine, Slash	*Pinus caribaea* Morelet
Pine, Spruce	*Pinus glabra* Walt.
Pine, Sugar	*Pinus lambertiana* Dougl.
Pine, Table-Mountain	*Pinus pungens* Lamb.
Pine, Virginia	*Pinus virginiana* Mill.
Pine, Western White	*Pinus monticola* Dougl.
Pine, Whitebark	*Pinus albicaulis* Engelm.
Pinyon	*Pinus edulis* Engelm.
Planertree	*Planera aquatica* (Walt.) Gmel.
Pondcypress	*Taxodium ascendens* Brongn.
Poplar, Balsam	*Populus tacamahaca* Mill.
Redbay	*Persea borbonia* (L.) Spreng.
Redbud, Eastern	*Cercis canadensis* L.
Redcedar, Eastern	*Juniperus virginiana* L.
Redcedar, Southern	*Juniperus lucayana* Brit.
Redcedar, Western	*Thuja plicata* Donn.
Redwood	*Sequoia sempervirens* (D. Don) Endl.
Rhododendron	*Rhododendron* spp.
Sassafras	*Sassafras albidum* (Nutt.) Nees
Silverbell, Carolina	*Halesia carolina* Ellis
Serviceberry, Downy	*Amelanchier arborea* (Michx. f.) Fern.
Sourwood	*Oxydendrum arboreum* (L.) DC.
Spruce, Black	*Picea mariana* (Mill.) B.S.P.
Spruce, Blue	*Picea pungens* Engelm.
Spruce, Engelmann	*Picea engelmanni* Parry
Spruce, Norway	*Picea abies* (L.) Karst.
Spruce, Red	*Picea rubens* Sarg.
Spruce, Sitka	*Picea sitchensis* (Bong.) Carr.
Spruce, Western White	*Picea glauca* var. *albertiana* (S. Brown) Sarg.
Spruce, White	*Picea glauca* (Moench) Voss.
Sugarberry	*Celtis laevigata* Willd.
Sweetbay	*Magnolia virginiana* (L.)
Sweetgum	*Liquidambar styraciflua* (L.)
Sycamore, American	*Platanus occidentalis* L.
Tamarack	*Larix laricina* (Du Roi) K. Koch
Tanoak	*Lithocarpus densiflora* (Hook. & Arn.) Rehd.
Torreya, California	*Torreya californica* Torr.

Tupelo, Black	*Nyssa sylvatica* Marsh.
Tupelo, Swamp	*Nyssa sylvatica* var. *biflora* (Walt.) Sarg.
Tupelo, Water	*Nyssa aquatica* L.
Walnut, Black	*Juglans nigra* L.
White-Cedar, Atlantic	*Chamaecyparis thyoides* (L.) B.S.P.
White-Cedar, Northern	*Thuja occidentalis* L.
White-Cedar, Port Orford	*Chamaecyparis lawsoniana* (A. Murr.) Parl.
Willow	*Salix* spp.
Willow, Black	*Salix nigra* Marsh.
Yellow-Cedar, Alaska	*Chamaecyparis nootkatensis* (D. Don) Spach
Yellow-Poplar	*Liriodendron tulipifera* L.

Common Names of Insects and Their Scientific Equivalents

Aphid, Balsam Woolly	*Adelyes (Dreyfusia) piceaa* Ratz.
Aphid, Spruce	*Aphis abietina* Walk.
Beetle, Black Hills	*Dendroctonus ponderosae* Hopk.
Beetle, Columbian Timber	*Corthylus columbianus* Hopk.
Beetle, Douglas-Fir	*Dendroctonus pseudotsugae* Hopk.
Beetle, Eastern Spruce Bark	*Dendroctonus piceaperda* Hopk.
Beetle, Engelmann Spruce	*Dendroctonus engelmanni* Hopk.
Beetle, Engraver or Ips	*Ips* spp.
Beetle, Hickory Bark	*Scolytus quadrispinosus* Say.
Beetle, June	*Phyllophaga* spp.
Beetle, Longhorned	*Parandra* spp.
Beetle, Mountain Pine	*Dendroctonus monticalae* Hopk.
Beetle, Red Turpentine	*Dendroctonus valens* Lec.
Beetle, Southern Pine	*Dendroctonus frontalis* Zimm.
Beetle, Southwestern Pine	*Dendroctonus barberi* Hopk.
Beetle, Western Pine	*Dendroctonus brevicomis* Lec.
Borer, Bronze Birch	*Agrilus anxius* Gory.
Borer, Hickory Spiral	*Agrilus arcutus* var. *torquatus* Lec.
Borer, Locust	*Cylene robiniae* Forst.
Borer, Poplar	*Saperda calcarata* Say
Borer, Turpentine	*Buprestis apricans* Hbst.
Borer, Two-Lined Chestnut	*Agrilus bilineatus* (Web.)
Budworm, Spruce	*Cacoecia fumiferana* Clem.
Butterfly, Pine	*Neophasia menapia* Feld.
Cankerworm, Spring	*Palaecrita vernata* Peck.
Caterpillar, Forest Tent	*Malacosoma disstria* Hubn.
Girdler, Hickory Twig	*Oncideres cingulatus* Say
Looper, Hemlock	*Nepytia phantasmaria* Stkr.
Moth, Douglas-Fir Tussock	*Hemerocampa pseudotsugata* McD.
Moth, European Pine Shoot	*Rhyacionia bouliana* (Schiff.)
Moth, Gypsy	*Porthetria dispar* L.
Moth, Pandora	*Coloradia pandora* Blake
Sawfly, European Spruce	*Diprion polytomum* Hart.
Sawfly, Jack Pine	*Neodiprion banksianae* Roh.

Sawfly, Larch	*Lygaeonematus erichsonii* (Hartig)
Sawfly, LeConte's	*Colaspis brunnea* (Fab.)
Sawfly, Red-Headed Pine	*Neodiprion lecontei* Fitch
Scale, Golden Oak	*Asterolecanium variolosum* (Ratz.)
Scale, Oyster Shell	*Lepidosaphes ulmi* (L.)
Tier, Lodgepole Needle	(*Eulia*) *Argyrotaenia* sp.
Tipmoth, Jack Pine	*Rhyacionia* sp.
Tipmoth, Nantucket	*Rhyacionia frustrana* (Comst.)
Weevil, Nut	*Curculio* spp.
Weevil, Pales or Snout	*Hylobius pales* Boh.
Weevil, Sitka Spruce	*Pissodes barberi* Hopk.
Weevil, White Pine	*Pissodes strobi* Boh.
Worm, Chestnut Timber	*Melittomma sericeum* Harris
Worm, Oak Timber	*Eupsalis minuta* Drury

Common Names of Diseases and Some of Their Causal Agents with Their Scientific Equivalents

Blight, Brown-Spot Needle	*Septoria acicola* (Thum.) Sacc.
Blight, Chestnut	*Endothia parasitica* (Murr.) A. & A.
Canker, Hypoxylon	*Hypoxylon pruinatum* (Klotsche) Cke.
Canker, Nectria	*Nectria* spp.
Canker, Tympanis	*Tympanis* sp.
Disease, Strumella	*Strumella coryneoidea* Sacc. & Wint.
Fomes, Rose-Colored	*Trametes subrosea* Weir (*T. carnea*)
Fungus, Incense-Cedar	*Polyporus amarus* Hedgc.
Fungus, Indian Paint	*Echinodontium tinctorium* E. & E.
Fungus, Quinine	*Fomes laricis* (Jack.) Murr.
Fungus, Red Belt	*Fomes pinicola* (Swartz) Cke.
Fungus, Ring Scale	*Fomes pini* (Thore) Lloyd
Fungus, Shoestring	*Armillaria mellea* (Vahl.) Quel.
Fungus, Velvet Top	*Polyporus schweinitzii* Fr.
Girdle, Pitch	Unidentified
Mistletoe	*Arceuthobium* (*Razoumofskya*) spp.
Poria, Brown Cedar	*Poria weirii* Murr.
Rot, Birch Brown	*Polyporus betulinus* (Bull.) Fr.
Rot, Birch White	*Fomes fomentarius* (L.) Gill.
Rot, Brown Butt	*Polyporus balsameus* Pk.
Rot, Brown Heart	*Poria sequoiae* Bonar
Rot, Brown Stringy	*Echinodontium tinctorium* E. & E.
Rot, Brown Trunk	*Fomes laricis* (Jack.) Murr.
Rot, Red-Brown Butt	*Polyporus schweinitzii* Fr.
Rot, Red Ring	*Fomes pini* (Thore) Lloyd
Rot, Top	*Stereum sanguinolentum* Alb. & Schw.
Rot, Western Red	*Polyporus ellisianus* (Murr.) Sacc. & Trott.
Rot, White String Butt	*Poria subacida* (Pk.) Sacc.
Rot, White Trunk	*Fomes igniarius* (L.) Gill.
Rot, Yellow Ring	*Poria weirii* Murr.

Rust, Eastern Gall	*Cronartium quercuum* (Berk.) Miyabe (*C. cerebrum*).
Rust, Southern Fusiform	*Cronartium fusiforme* (Pk.) Hedgc. & Hunt.
Rust, Western Gall	*Cronartium harknessii* (Moore) Meinecke
Rust, White Pine Blister	*Cronartium ribicola* Fisch.

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